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ASSESSMENT & IMPLEMENTATION OF IN-STREAM VALUE STUDIES FOR THE NORTHERN GREAT PLAINS

Contract Number 68-01-2653

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TONGUE RIVER INSTREAM FLOW CRITERIA

Section 1

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TONGUE RIVER INSTREAM FLOW CRITERIA

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INTRODUCTION

Various methodologies have been formulated and utilized by different agencies and organizations, for the determination and recommendation of minimum streamflows. While the methods used are varied and often dissimilar, they all have one common denominator. The flow criteria on which the methods are based, are selected in terms of measured or estimated requirements of the fish living in the stream.

Methodologies employed by the states of California, Oregon, and Montana include provisions for insect productivity, although the criteria may be too broad to be of much use for some of the methodologies (Bovee, 1974). The state of Washington incorporates a water quality model for dissolved oxygen into its streamflow recommendation procedure, and is the only state to follow this technique. None of the methodologies consider as flow criteria, such non-biotic phenomena as surface ice formation, sediment transport capacity, water temperature, or salinity. It can be demonstrated that reduced streamflow may have a great influence on these parameters, perhaps to the point that a change in some non-biotic parameter will have a deleterious effect on the fishery, even though the streamflow is adequate for fish and invertebrate habitat requirements.

The objectives of this study include the implementation of a methodology for the recommendation of minimum streamflow on a medium sized river containing a "warm-water" fish community; an evaluation of the suitablilty of the methodology; and an evaluation of flow criteria, including nonbiotic factors, used in making the flow recommendation.

This is an interim report. Therefore, much of the data is incomplete, making it unwise to draw conclusions at this writing. However, some trends have been detected, and these trends will be expressed and developed where possible.

THE STUDY AREA

The Tongue River in southeastern Montana was chosen as the study stream for this project. This river is a medium sized stream, carrying approximately 46 m^3/sec (2000 cfs) at bankfull stage. It contains a warm-water fish community throughout most of its length, although a fair trout community exists in its upper reaches.

Streamflow is modified by a 61 million cubic meter (50,000 AF) reservoir located approximately 40 km upstream from the town of Birney, Montana. For the first 16 km below the dam, the river flows through a rugged canyon. From the mouth of the canyon, it becomes a broadly meandering stream with a wide floodplain as it flows northeast the remaining 290 km to its confluence with the Yellowstone River. Figure 1 shows a map of the Tongue River with major study sites.

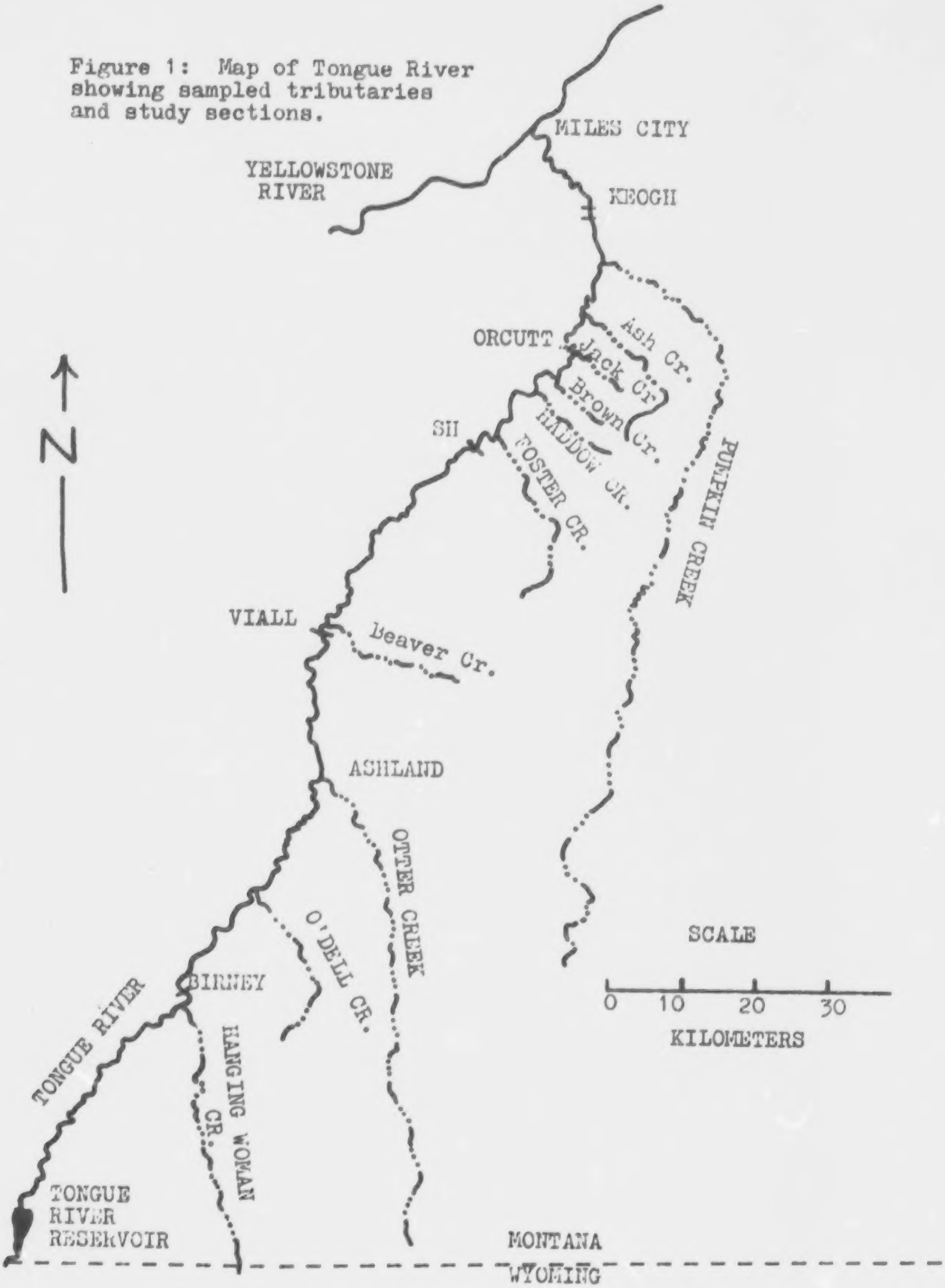

MILES CITY
YELLOWSTONE RIVER
KEOGH
ORCUTT
Ash Cr.
Jack Cr.
Brown Cr.
HADDOW CR.
SH
FOSTER CR.
PUMPKIN CREEK
N
VIALL
Beaver Cr.
ASHLAND
OTTER CREEK
O'DELL CR.
SCALE
BIRNEY
TONGUE RIVER
HANGING WOMAN CR.
0
10
20
30
KILOMETERS
TONGUE RIVER RESERVOIR
MONTANA
WYOMING

Figure 1: Map of Tongue River showing sampled tributaries and study sections.

Throughout its length, the Tongue River has a fairly high width to depth ratio. Probably due to the loss of sediment, and the resultant gain in energy, the streambed is armored from the dam downstream to near the vicinity of Birney. Below Birney, downstream to the Viall Ranch Section, some armoring is apparent, but not so distinctly as in the upper sections. The river approaches an equilibrium condition through the reach between the Viall Ranch and the Orcutt Ranch. Below the confluence of Pumpkin Creek, the stream more closely resembles a typical alluvial stream, and may approach an aggradational situation. However, in all study sections, areas of rapids and riffles are common, although the size of the bottom materials is noticeably smaller in the downstream sections.

FLOW CRITERIA

Flow criteria based on fishery requirements have been tentatively established by using the stonecat (*Noturus flavus*) as an indicator species. These criteria apply only to the rearing or non-spawning period.

The selection of the stonecat as an indicator species was based primarily on literature research which showed this species as one associated with fast, shallow water areas. This is the type of habitat which is most severely affected by reduced streamflow. In addition, the stonecat is an easy species on which to obtain field data. It is easily recognizable when stunned by electrofishing gear, and it is common throughout the length of the Tongue River.

Riffle utilization by stonecats was examined by electrofishing techniques as described by Vincent (1971). Whenever a stonecat was captured, a small marker buoy was dropped at the location from which the fish had come. This procedure was quite accurate, as it was usually possible to see exactly where the fish had been. The parameters of depth, velocity, and bottom type were measured and recorded for each buoy.

Stonecats in the Tongue River are normally associated with substrates ranging in size from small cobble (6.4 cm median diameter) to boulders, with the heaviest utilization in the 128 to 256 mm size class.

The mean depth of 203 stonecat locations was 45 cm, with a standard deviation of 13.7 cm. The mean velocity of the locations was 64 cm/sec, with a standard deviation of 19.6 cm/sec. Table 1 illustrates the occurance of stonecats as a function of depth and velocity.

Table 1: Occurance of stonecats with respect to depth and current velocity

	DEPTH (cm)					
VELOCITY (cm/sec)	< 15	16-30	31-45	46-60	61-75	> 76
< 15	0	0	1	1	1	1
16-30	0	0	3	0	0	0
31-45	0	6	7	10	8	1
46-60	0	3	23	27	7	1
61-75	1	8	18	21	2	1
76-90	0	3	24	11	1	0
90-105	0	0	4	4	0	0
> 106	0	1	3	1	0	0

The outlined block in Table 1 contains 61% of all locations. The depths and velocities represented by the outline are suggested as flow criteria for the rearing period. This includes depths of 30 to 60 cm and velocities of 45 to 90 cm/sec, over a stream control, such as a rapids or riffle area. 78% of all stonecats were found within this range of depths, and 74% within this range of velocities.

METHODOLOGY

The methodology used in this study is a detailed data method as described in Bishop and Scott (1973). At each of four mapping sections, four transects are established at intervals of 5 to 7 meters across the study area, and the depth, velocity, and distance from shore, measured at 1.5 meter intervals across each transect. This data is then recorded to scale on separate gridded maps for depth and velocity. Contour lines of equal depths and velocities are drawn, using interpolation to locate points between transects.

A composite map is then constructed for each section, for each mapped discharge, and areas meeting the criteria of depth and velocity are outlined. From the composite map, the actual area of preferred habitat may be determined planimetrically. Contour maps and their composites are given in Appendix B.

The area meeting depth and velocity criteria, as shown on each composite map, may then be plotted against the discharge for each map. No discharge-area plots are given at this time, as there are not enough points. However, it can be seen from the maps in Appendix B, that the optimum discharge will probably be around 12.7 to 14.1 m^3/sec (450 to 500 cfs). From the method described by Bishop and Scott (1973), the recommended minimum discharge would be around 9.5 to 10.5 m^3/sec (340 to 370 cfs).

In order to more accurately describe the optimum conditions, more maps must be drawn for discharges between 11.3 and 17 m^3/sec (400 to 600 cfs). In addition, maps should also be drawn for discharges near the recommended range in order to evaluate the amount of preferred habitat remaining at that discharge.

The results from this methodology appear to be satisfactory in all respects. However, a major criticism often raised, is the time requirements in implementing the methodology. A full man-day is required on the Tongue River, for each mapping station. Actual wading time ranges from 6 hours for the Birney and Orcutt sections, to about 5 hours for the Viall and SH Ranch sections. In addition, about 12 man-hours are required in compiling each map. Therefore, each data point on the area-discharge plot represents a time investment of about 24 man-hours.

ICE FORMATION

Despite the common occurance and economic importance of ice formation in rivers, there is a lack of basic information concerning this phenomenon. The works of Barnes (1906, 1926) contain some of the most detailed summaries of data in this area, but little additional information has been added since then.

The mechanics of "freeze-up" have been fairly well agreed upon by several authors. When the entire water mass is near the freezing point, only a slight amount of supercooling at the surface is required for the formation of ice crystals. While the ambient air temperature must be considerably below the freezing point, the degree of supercooling is rarely more than $-0.01^{\circ}C$ (Schaefer, 1950). Where turbulence is large, the mix-interval is very short, enabling surface formed ice crystals to be entrained and pulled below the surface while other crystals are still forming at the surface. The combined effects of physical removal of ice crystals, turbulent removal of latent heat, and a large source of near-freezing water, make turbulent areas prime producers of ice crystals, called frazile ice (Parsons, 1940). Schaefer (1950) measured concentrations of ice crystals approaching $10^6/ m^3$ in the Mohawk River of New York, during an active frazile ice formation period.

The rate at which frazile ice is formed is important to the formation of a continuous ice sheet. It is free floating frazile ice, jamming together and adhering to banks and other pans of frazile ice, which forms the initial surface ice sheet. Here, the strength of the current plays an important role in the formation of the surface sheet. Where current velocities are high, especially where turbulence is also high, the frazile ice tends to remain in suspension. Where velocities and turbulence are low, the ice crystals more readily float to the surface, where they may freeze together rapidly.

Once a continuous layer of surface ice has formed over an area, frazile ice is no longer produced at that location. However, frazile ice may be formed continuously from isolated pockets of open water. If a river is dammed, the upper reaches tend to remain open later in the season, so that these areas may just start producing frazile ice long after the lower reaches have frozen. Barnes (1906) noted that frazile ice was present under a thick layer of surface ice on the Montreal River. The only identifiable source of this frazile ice was about 160 km upstream from his measuring stations.

Thickening of the initial ice sheet proceeds through conduction, and capture of frazile ice travelling beneath the sheet ice. If the thickening process depended solely on the conduction of heat through the ice sheet, the rate of thickening would follow the form

$$E = \sqrt{\frac{2 \theta K t}{L S}}$$

where,

E = thickness in cm

θ = ambient air temperature

K = thermal conductivity of ice=.0057 cal/deg/cm^2/sec

t = time in seconds

L = heat of fusion= 80 cal/gram

S = density of ice=.9166 gram/cm^3 (Barnes, 1906).

Figure 2 illustrates graphically the time required for various thicknesses to be attained at different temperatures. In addition, if thickening were due solely to conduction, the ice sheet should be nearly planar on its under side, since the rate of conduction should be uniform across a given cross section.

In reality, the rate of thickening may be considerably faster in some areas, slower in others, and the underside of the ice sheet is seldom planar. Figures 3, 4, and 5 illustrate actual measurements across areas of known bottom conformation. Notice, that in general, the contour of the undersurface of the ice roughly parallels the bottom contour, unless a region of deep, fast water is encountered.

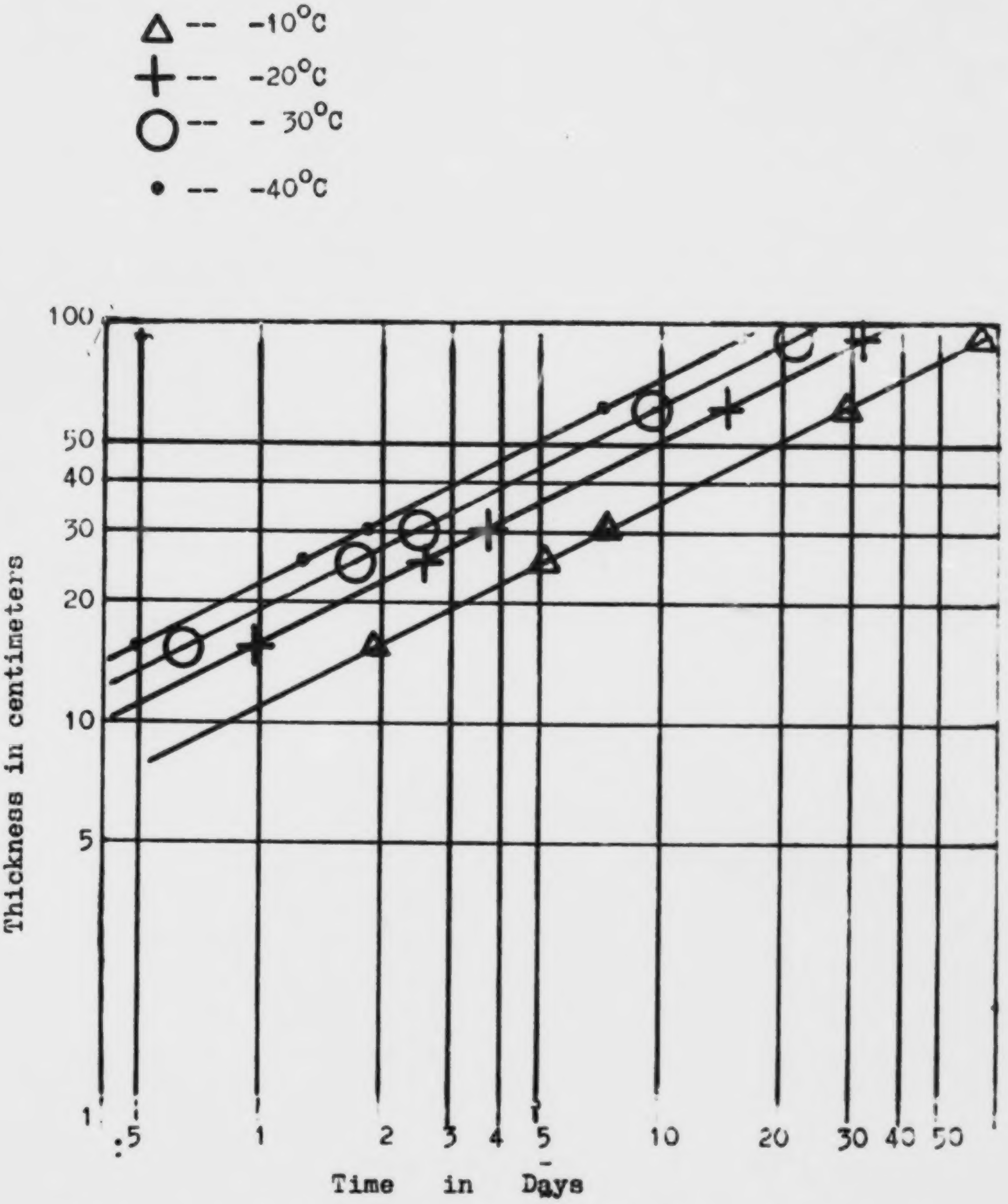


Figure 2 : Rate of Growth of Ice Sheet Due to Conduction at Four Different Temperatures.

Figure 3 : Ice Measurements Across Transect # 4, SH Ranch Section, 2/13/75. Cross-hatched area represents surface ice sheet.

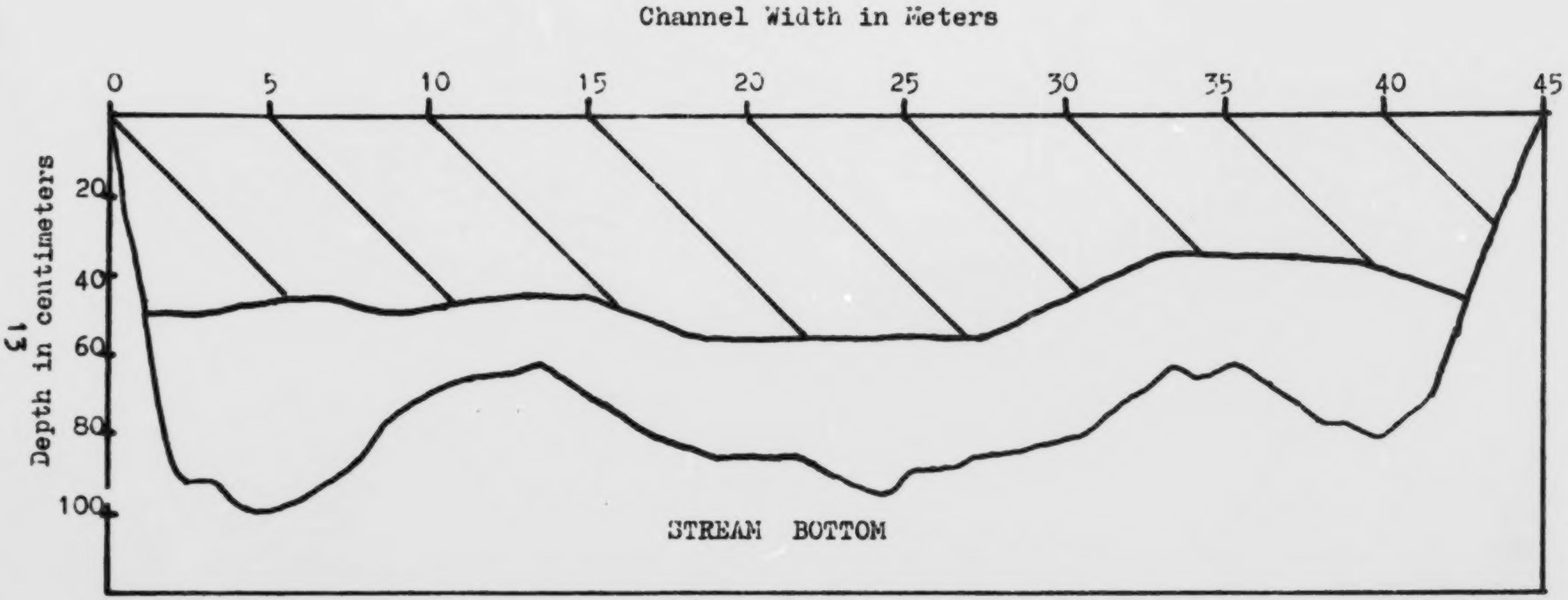


Figure 4 : Ice Measurements Across Transect #3, Viall Ranch Section, 2/20/75.
Cross-hatched area represents surface ice sheet.

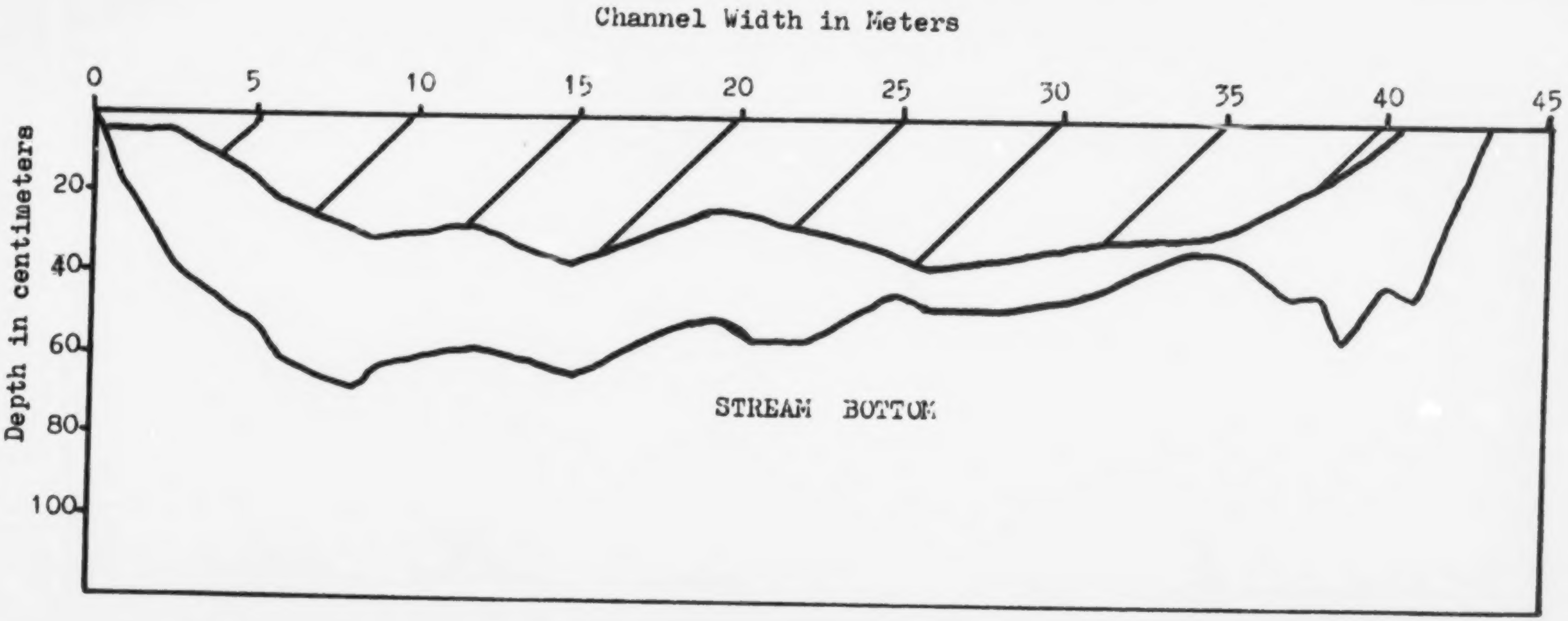
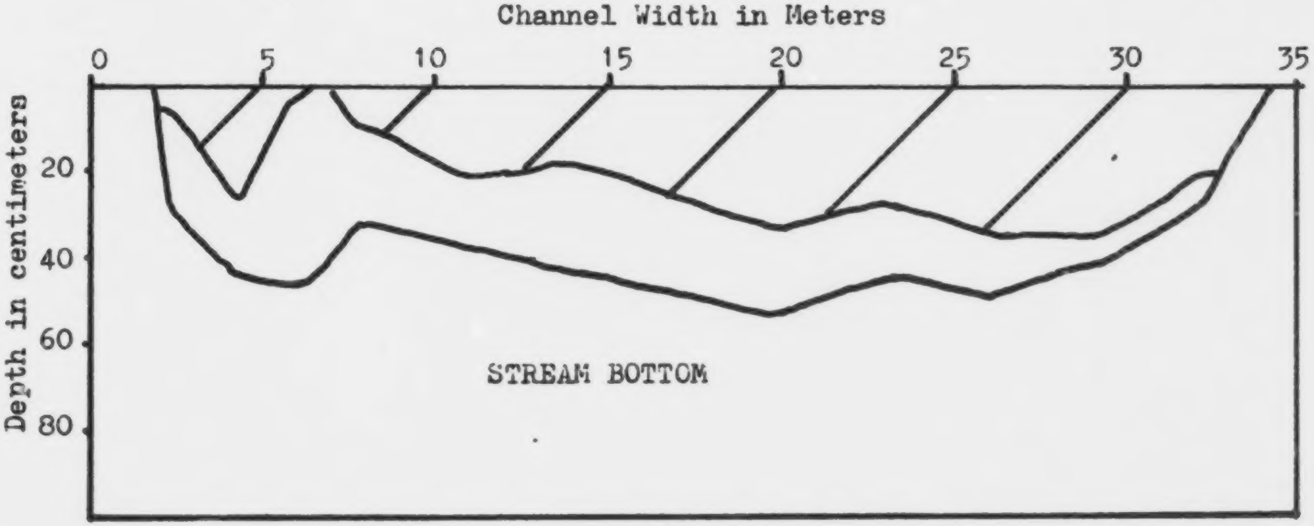


Figure 5 : Ice Measurements Across Transect #3, Right Channel, Birney Section, 2/26/75.

Cross-hatched area represents surface ice sheet.



Current meter measurements were made through the ice at numerous locations to determine whether there was any correlation between ice thickness and current velocity. This data is listed in Appendix A by location. Figure 6 is a scatter diagram of ice thickness plotted against current velocity for all measurements, excluding places where the ice had frozen to the bottom. For this population of data, the least square regression line is given by the equation

$$T = 37.7\ V^{-0.202}.$$

The non-linear correlation coefficient was computed to be -.462, following procedures described in Croxton and Cowden (1947).

Because the ice sheet creates an additional friction surface, it has a decided effect on the current velocity. As ice occupies more and more space between the surface and the stream bottom, this drag effect becomes more pronounced. For example, if the ice sheet in an area is 20 cm thick, but the envelope of open water beneath the ice is only 1 cm, the effect on the current will be greater than 20 cm of ice with 40 cm of open water beneath it.

In order to reduce depth effects, measuring stations which had depths less than 40 cm were omitted from the data plot. Figure 7 is a scatter diagram of this data.

Figure 6 : Relationship between ice thickness and current velocity; all samples included.

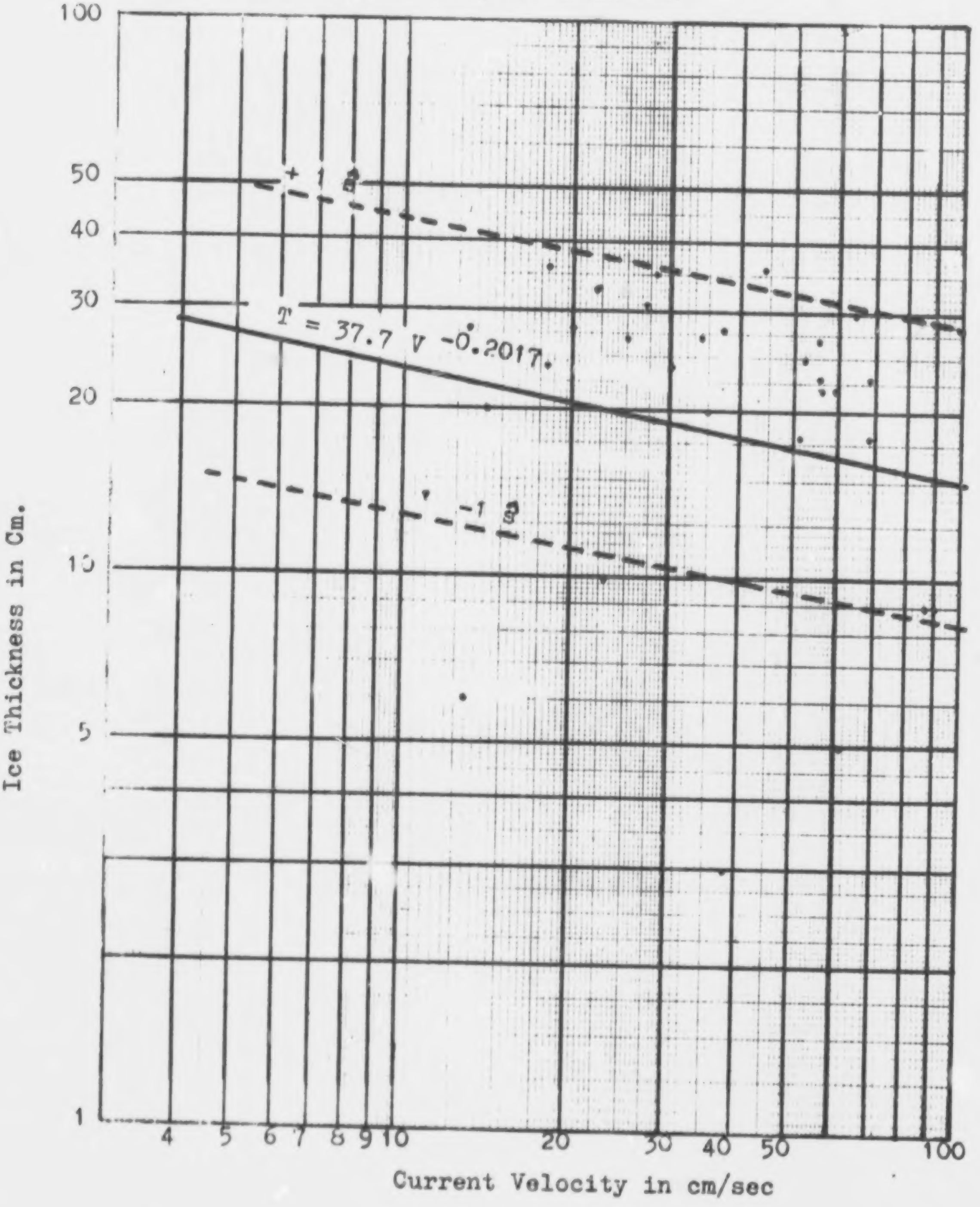


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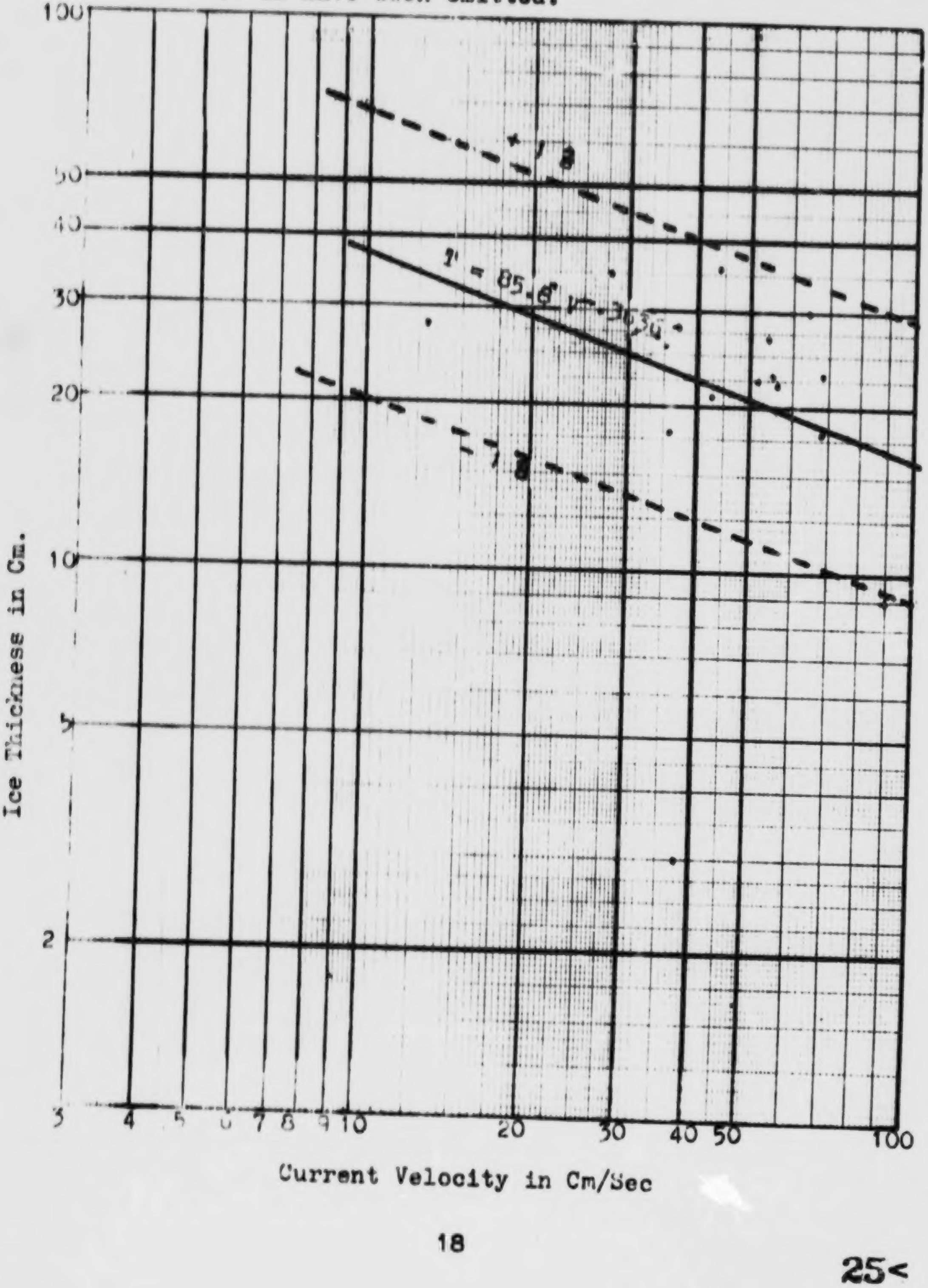
Figure 7 : Relationship between ice thickness and current velocity. Samples with water depths less than 40 cm have been omitted.



The least square regression line for this data plot is given by

$$T = 85.5\ V^{-0.364}$$

where

T = ice thickness in cm

V = current velocity in cm/sec.

The non-linear correlation coefficient for this scatter diagram is slightly higher, -.532, indicating that the depth probably does influence the current velocity. Because measurements were made periodically over a two month period, the effects of differential conduction cannot be eliminated from the data. However, the measurements were made after the entire river had been frozen for over a month. Therefore, the effects of conduction should have had time to equalize over the length of the river.

Surface ice plays an important role in numerous areas of aquatic biology and channel morphology. It acts as an insulating barrier to back radiation, which eliminates the formation of potentially destructive anchor ice. In this sense, surface ice is a beneficial agent, especially by maintaining productivity of aquatic insects in shallow water areas. However, as the surface sheet becomes thicker, it can cause serious problems.

Several locations were found where the ice had frozen to the streambed. At these sites, the ice was not simply frozen lightly to the largest protrusions, but had actually frozen solidly several centimeters down into the substrate. At some areas, where the stream was especially wide and shallow, an estimated 1/3 of the channel width was lost to this phenomenon.

Reduced streamflow would have the effects of reducing both the depth and the velocity of the water. Based on observations, such as figures 3, 4, and 5 , and on the relationship between ice thickness and velocity, it appears that reduced streamflow during the winter will lead to more areas where the ice extends into, or very near to, the streambed. While fish can escape into deep holes, many aquatic insects, particularly those which are highly current oriented, will be adversely affected. In addition, a substantial reduction in the thickness of the envelope of open water over shallow areas would tend to reduce the circulation of fresh water in pools. This could result in stagnation and oxygen depletion such as described by Thompson (1925).

River ice also plays a significant role as a geomorphic agent. Expansion of an ice sheet, as a result of a rise in temperature following a period of cold temperature, can develop a significant amount of thrust against steep-walled banks and bridge pilings. The amount of expansion pressure is a function of the ice thickness, the rate of temperature rise, and the slope of restraining bank. Where the slope of the restraining bank is small, the ice sheet can slide up the bank on expansion, with little or no effect. However, against a vertical bank a 30 cm sheet of ice may develop about 66,000 newtons per square meter pressure (Rose, 1946). This figure may be more or less depending on the upstream and downstream restraint. While expansion pressures are probably not great enough to cause deformation of the bank, they may be great enough to cause some pressure melting against large protrusions in the bank matrix.

Whether by pressure melting, or by simply freezing to the bottom, the ice sheet is apparently quite efficient at "plucking", a common phenomenon associated with glaciers. Overturned ice blocks invariably reveal large rocks imbedded in them. Plate I shows one such block with many small to medium cobbles entrapped. A large amount of sand and gravel is also incorporated in the matrix, as can be seen by the dirty appearance of the ice. The amount of coarse sediment moved in this manner has not been quantified for comparison with the amount moved by ordinary fluvial processes, but it is interesting to note that much larger particles may be moved at a correspondingly low discharge.

PLATE I: Overturned ice sheet with several small cobbles imbedded in undersurface. Size of particles ranges from about 16 to 64 mm, median diameter.

Particles in the bed and banks are also rearranged considerably during the spring melt. Where surface ice had been frozen to the bed and banks, large an small particles alike are wrenched loose when the ice cakes begin moving downstream. Where a controlling feature in the channel is encountered, such as a shallow area, channel constriction, or block of ice which is still firmly anchored, an ice jam is formed. When these jams finally break loose, a sudden surge of water and ice is released.

Ice break-up may be an important factor in the supply of sediment to the river. During this time, large blocks of ice often are driven into the bed or banks, with an action similar to a huge bulldozer. Wading in the river after break-up reveals that any packing of bed materials which has occurred during the year has been disrupted by the passage of the ice. Substrate materials are obviously loose, often to the point that wading is difficult because of the poor footing.

It would seem that the movement of the ice would be a severe hazard to the animals living in the river. However, little is known about mortalities associated with break-up. In fact, it is likely that this phase of life in rivers will be unexplored because the dangers involved in sampling would be prohibitive.

A more quantifiable effect of ice movement is the damage done by ice and high water to man-made structures along the river, such as bridges, pumping stations, and head gates. Each year, several of these structures are lost to ice jams. As the occurance of ice jamming increases, so does the threat of structural damage.

If the water levels are reasonably high when the ice first forms, the ice will probably freeze to the bottom in fewer areas. If the water is fairly high during break-up, there will be a greater potential for passage, and fewer places where ice cakes can hang up in the channel. Therefore, if the water levels in the river are fairly high during break-up, the ice will flow through the system quite uniformly.

Conversely, reduced streamflow during the winter may result in a thicker layer of river ice, which will be anchored to the bottom in more places. Insufficient streamflow during break-up is likely to result in a more severe ice jamming condition, because there will be less room for passage over shallow areas, and more places where ice is frozen to the streambed. In turn, this will result in a greater risk of structural damage along the watercourse.

SEDIMENT TRANSPORT

This task has several broad objectives, including: (1) the determination of the amount and size distribution of sediment particles moving in the river a various discharges, (2) the determination of the amount and size distribution of sediment entering the river from tributaries, (3) and a comparison of the characteristics of the bedload and the suspended load.

Suspended sediment samples were taken with a US DH-48 suspended sediment sampler with a ¼" nozzle. These samples were taken by the equal transit rate method as described in Guy and Norman (1970). Bedload samples were taken at each suspended sample vertical with a Helley-Smith pressure difference sampler. Composite samples only were taken at the tributaries. However, on the mainstem river, a series of upstream and downstream samples were taken at each mapping site. One series of samples was taken near the top of the "control" (the high area of a rapid or riffle which controls streamflow by its damming effect), and another series was taken at the bottom of the control. A significant increase in sediment load at the lower station would indicate scour across the mapping site. A decrease would indicate fill. By comparing the size distribution of particles at the two transects, it is possible to determine which sizes of particles are being picked up or deposited at different stages of the streamflow. It is also possible to identify the wash load, the sediment which simply washes across the section.

During periods of fairly low water, samples were taken by wading. During high water, a portable suspension system consisting of a long rope, tied to a tree on either bank, and a small rubber raft attached to the rope, was used for sampling.

Suspended samples were analyzed by methods described in Guy (1969). Whenever an adequate amount of sample was available, the sample was wet-sieved through a .062 mm sieve to separate the sand from the silt-clay fraction. The filtration method was used if the amount of clay was low. Large concentrations of clay clogged the filters, and samples containing such were evaporated. In order to avoid problems with dissolved solids, evaporation samples were allowed to settle, decanted, and washed with distilled water. This process was then repeated ~~again~~ before evaporation. Prior to washing, an aliquot of native water was removed for gravimetric analysis of total dissolved solids. Organic material was removed by treatment with 7% hydrogen peroxide prior to analysis.

Bedload samples were treated with hydrogen peroxide for organic removal, heated to dryness, and dry-sieved.

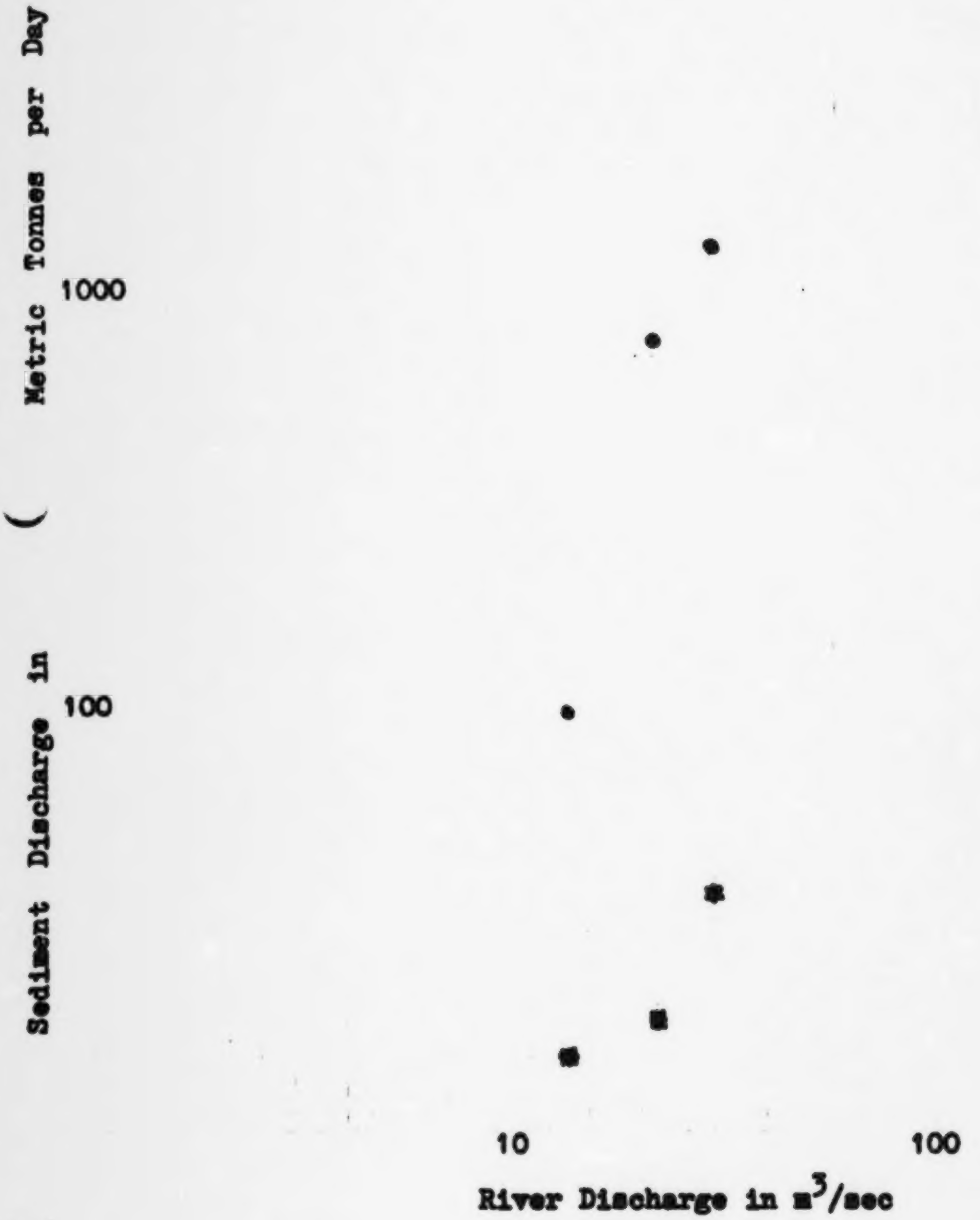
Results from the spring sampling program are listed in Appendix C by stream and location. Suspended sediment discharge and bedload discharge are plotted against river discharge in figures 6 through 13. Some of the river samples in Appendix C contain references to stations. Station A refers to the transect across the upstream control. The reference R 1/3 means that the samples were taken from the right one-third of the channel, facing downstream. M 1/3 refers to the middle third, and L 1/3 refers to the left third.

Few definitive relationships between stream discharge and sediment discharge are apparent from the data. However, it can be seen easily that for all discharges measured, the suspended fraction accounts for most of the sediment transported. Table 2 summarizes the data from Appendix C.

Table 2: Distribution of sediment between the suspended fraction and the bedload fraction.

Station	Q_r m^3/sec	$\bar{Q}_s$ tpd	$\bar{Q}_{bl}$ tpd	% Bedload	%Suspended	Silt-Clay %
Orcutt	13.6	98	15	13	87	--
	21.9	760	19	2	98	78
	30.0	1286	37	3	97	78
SH Ranch	17.5	253	25	9	91	--
	33.9	1478	23	2	98	74
Viall	12.8	100	28	22	78	--
	15.8	61	2.4	4	96	--
Brown Cr.	.5	1400	.3	.02	99.98	45
	.1	25	0	0	100	100
Haddow Cr.	.5	840	1.2	.1	99.9	92
	.8	574	3.4	.6	99.4	91

Figure 8: Sedimont Discharge vs. River Discharge, Orcutt Ranch Section.
o Suspended Fraction (average)
* Bedload Fraction (average)



Full Logarithmic [illegible] Cycle

Figure 9: Sediment Discharge vs. River Discharge, SH Ranch Section.
o Average suspended fraction
+ Average Bedload fraction

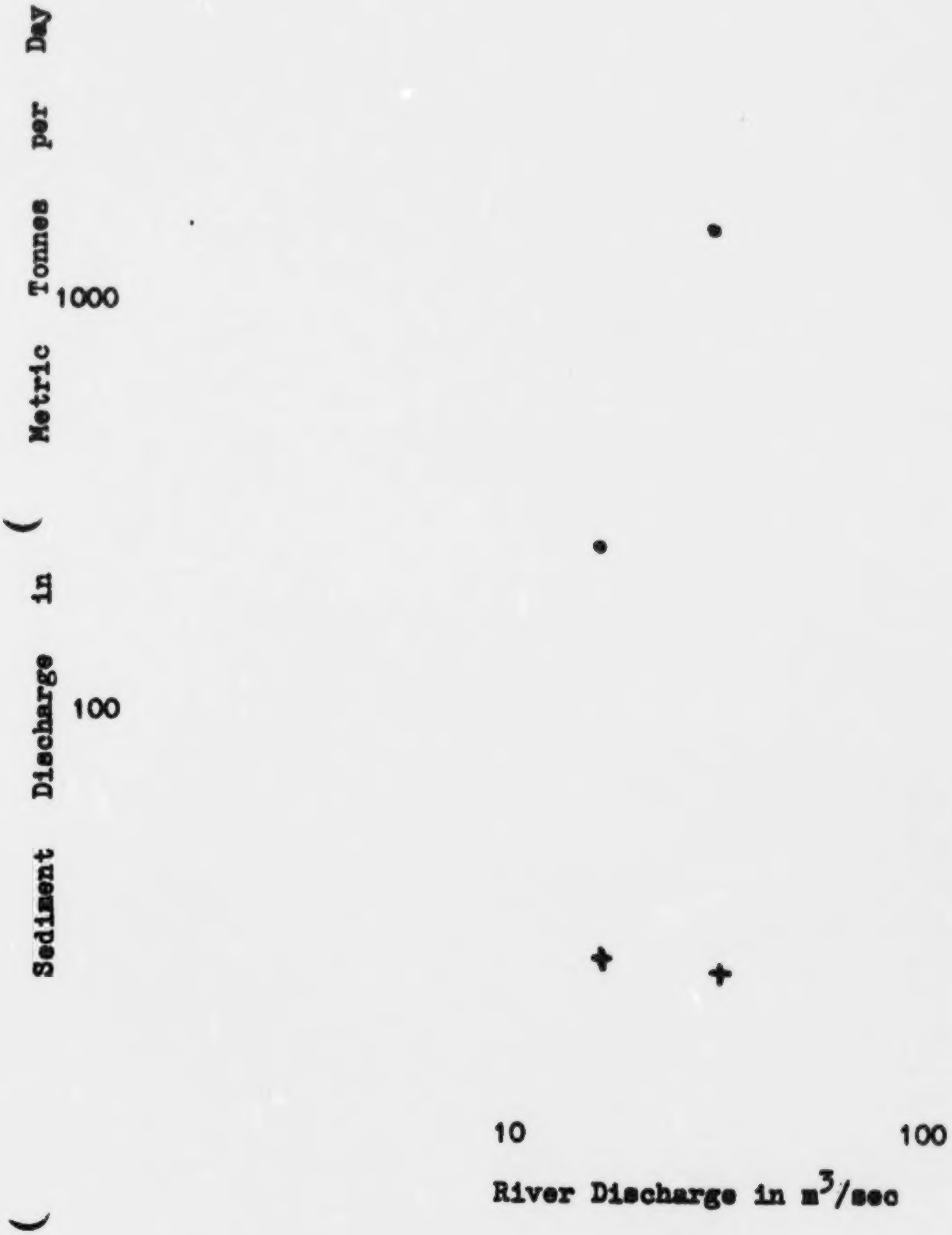
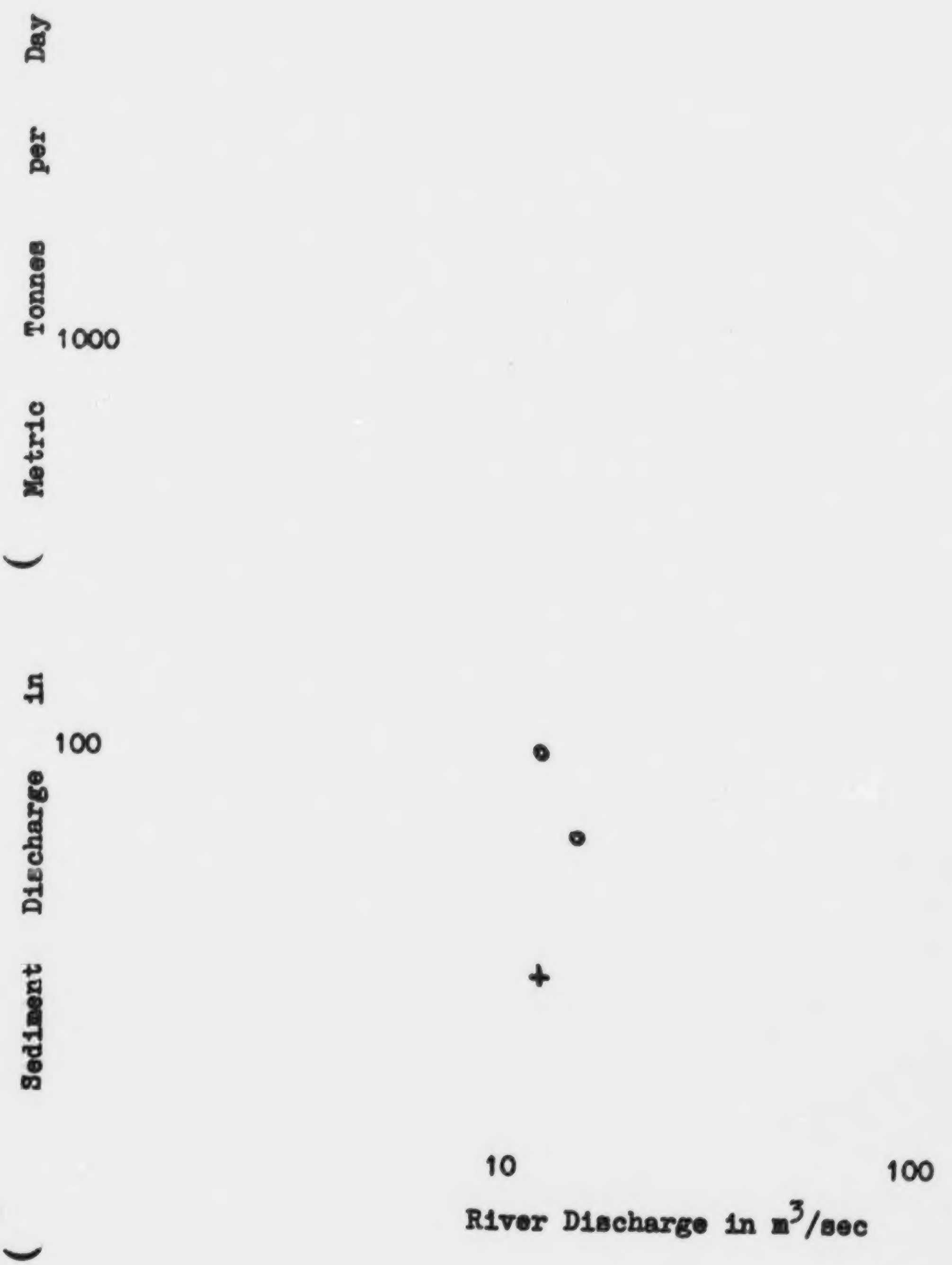


Figure 10: Sediment Discharge vs. River Discharge, Viall Ranch Section.
o Average suspended fraction
+ Average bedload fraction



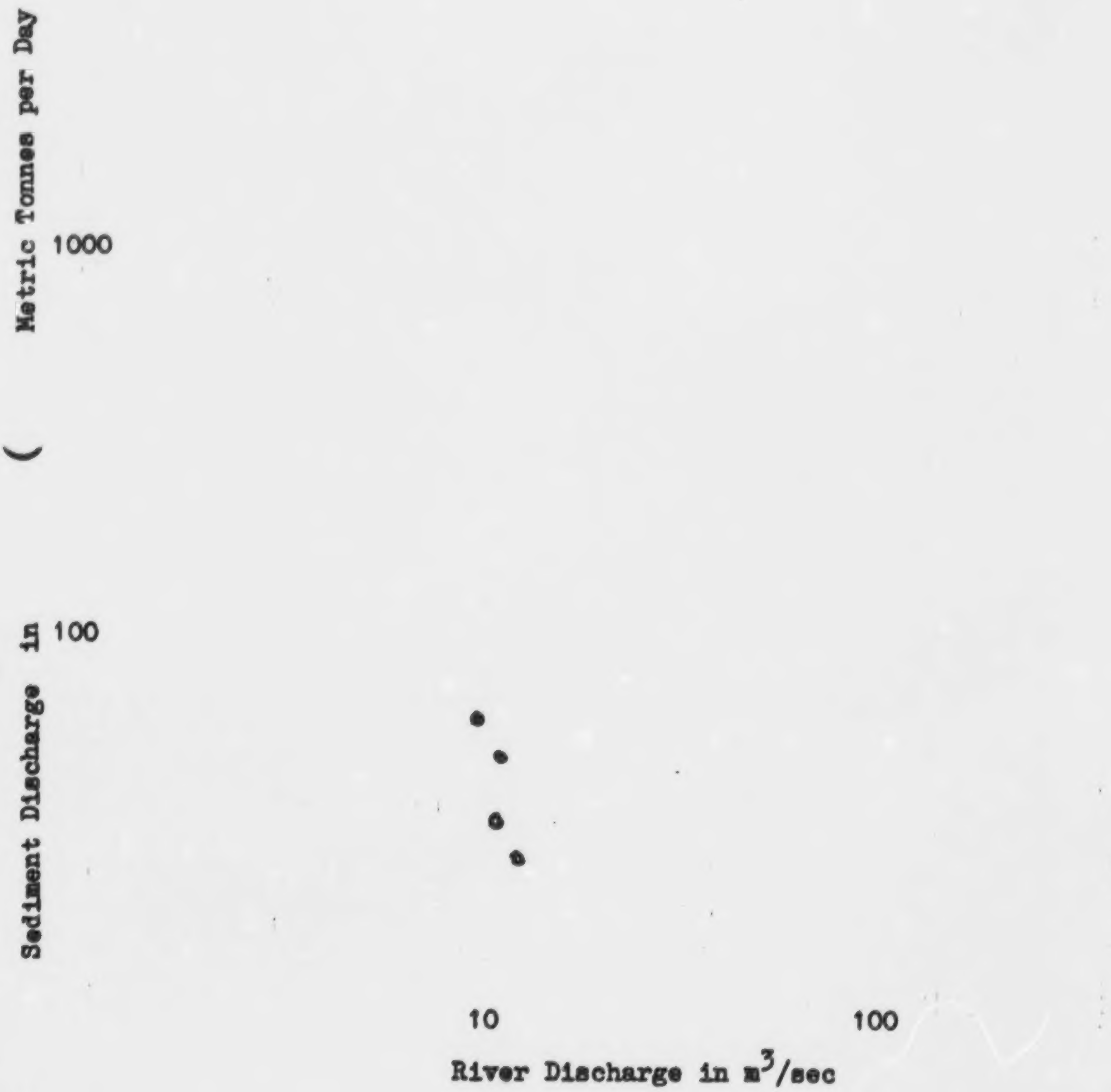


Figure 11:
Sediment Discharge vs. River Discharge, Birney Section.

o Suspended Sediment (Average)
* No bedload movement was detected in any of the samples.

Figure 12: Sediment Discharge vs. Stream Discharge. Haddow Creek at Tongue River Road.

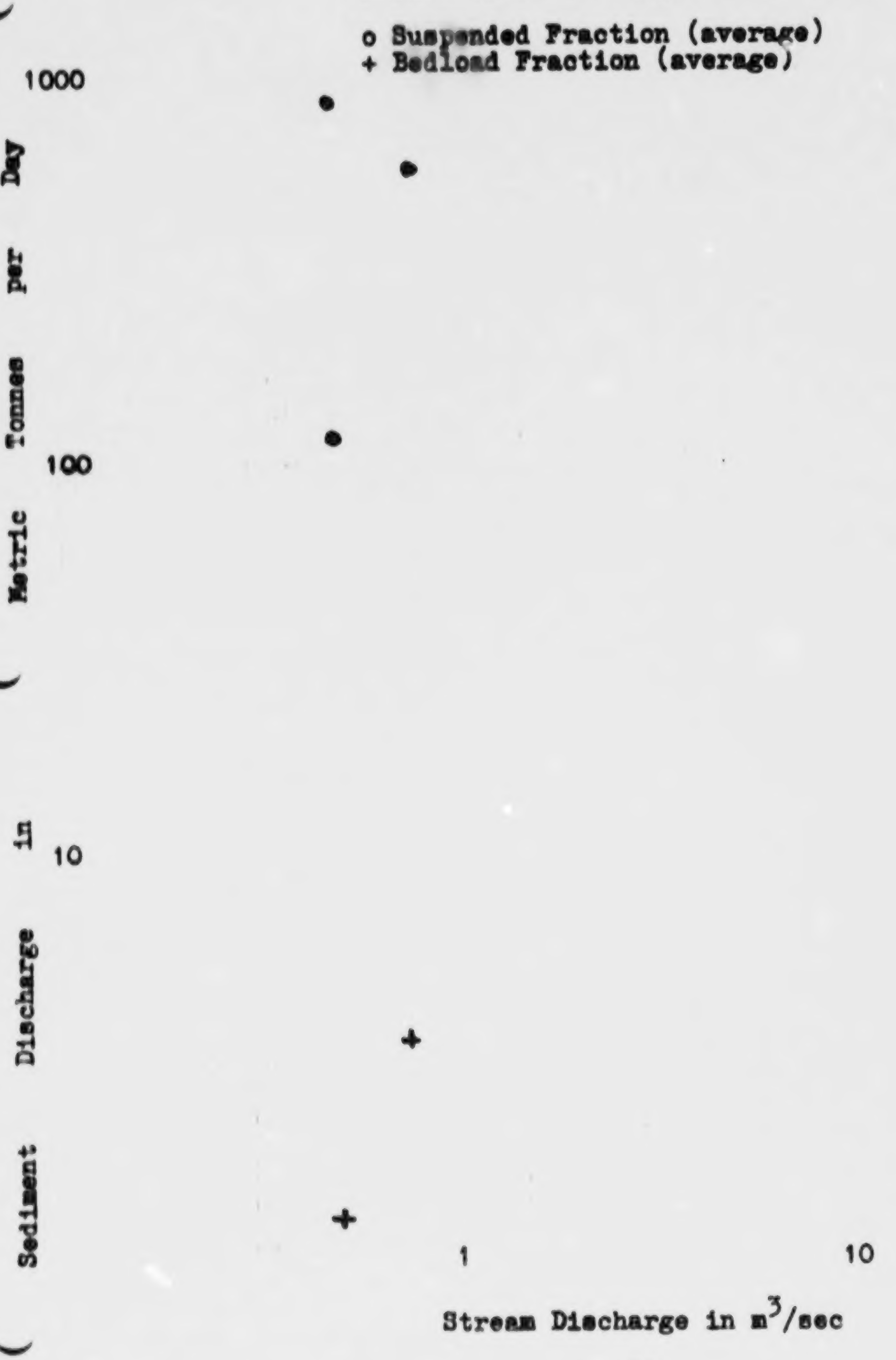


Figure 13: Sediment Discharge vs. Stream Dâácharge, Brown Creek at Tongue River Road.
o Suspended fraction
+ Bedload fraction

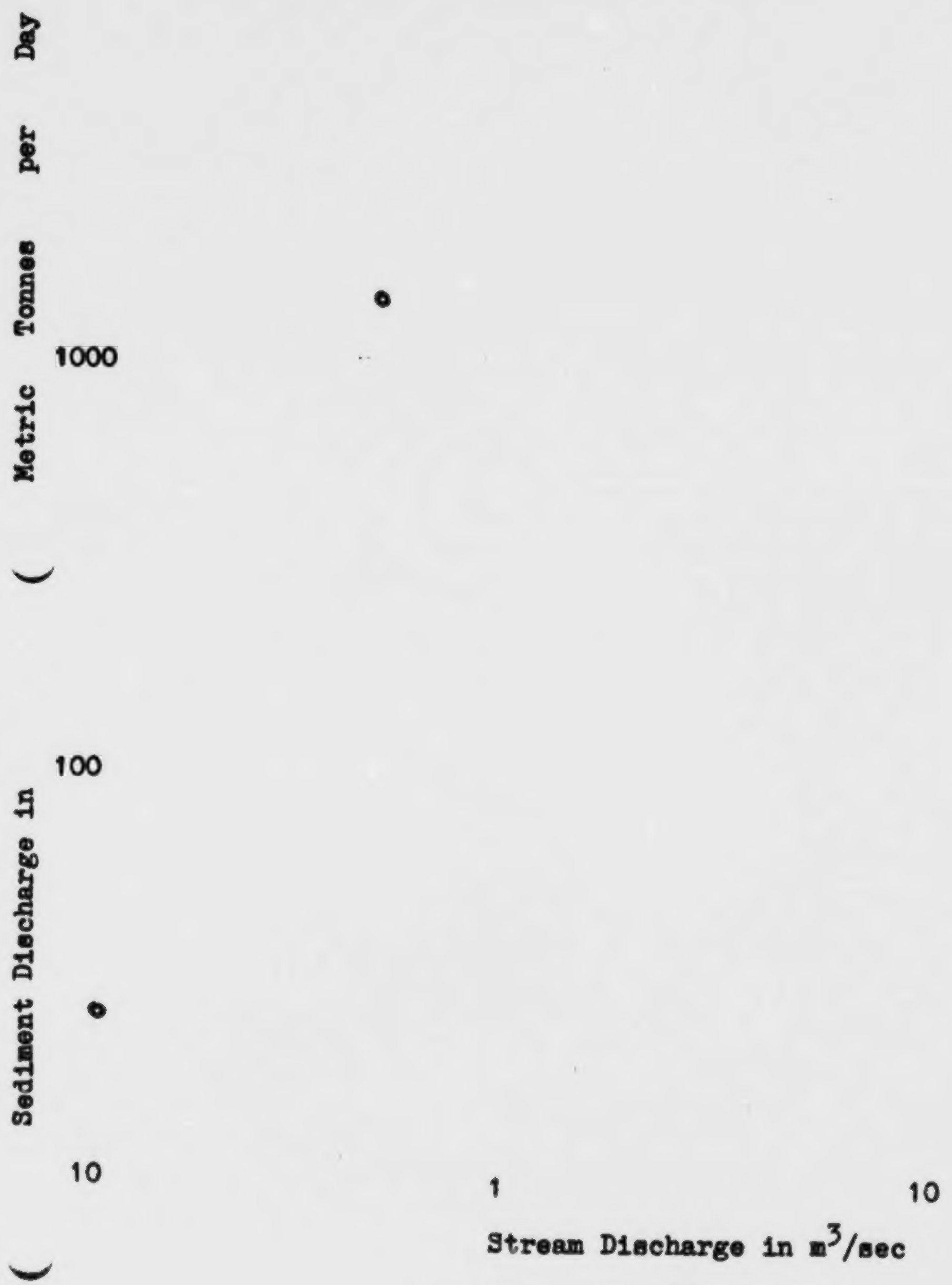
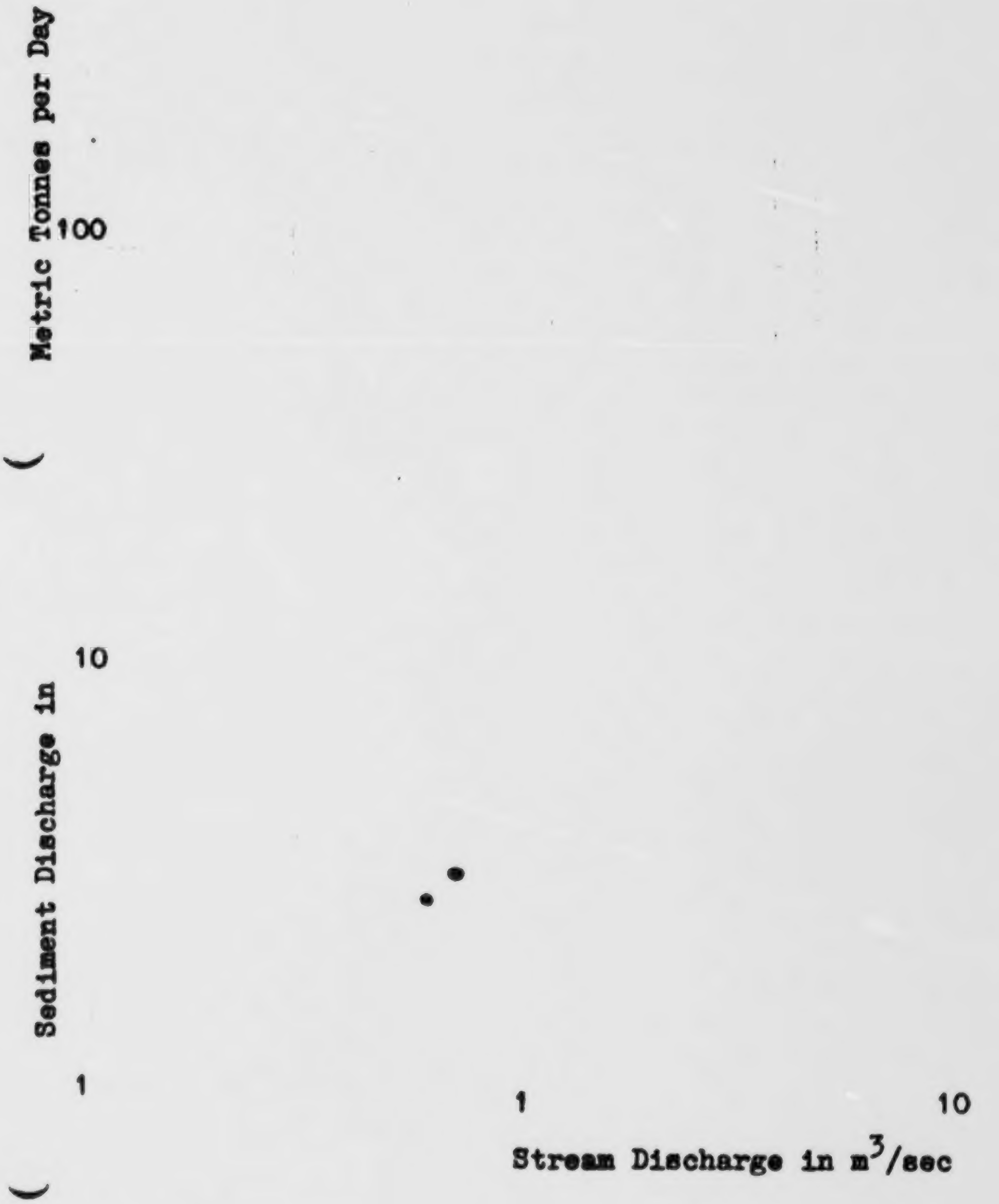


Figure 14: Sediment Discharge vs. Stream Discharge, Otter Creek at Ashland, Montana
o Suspended sediment only



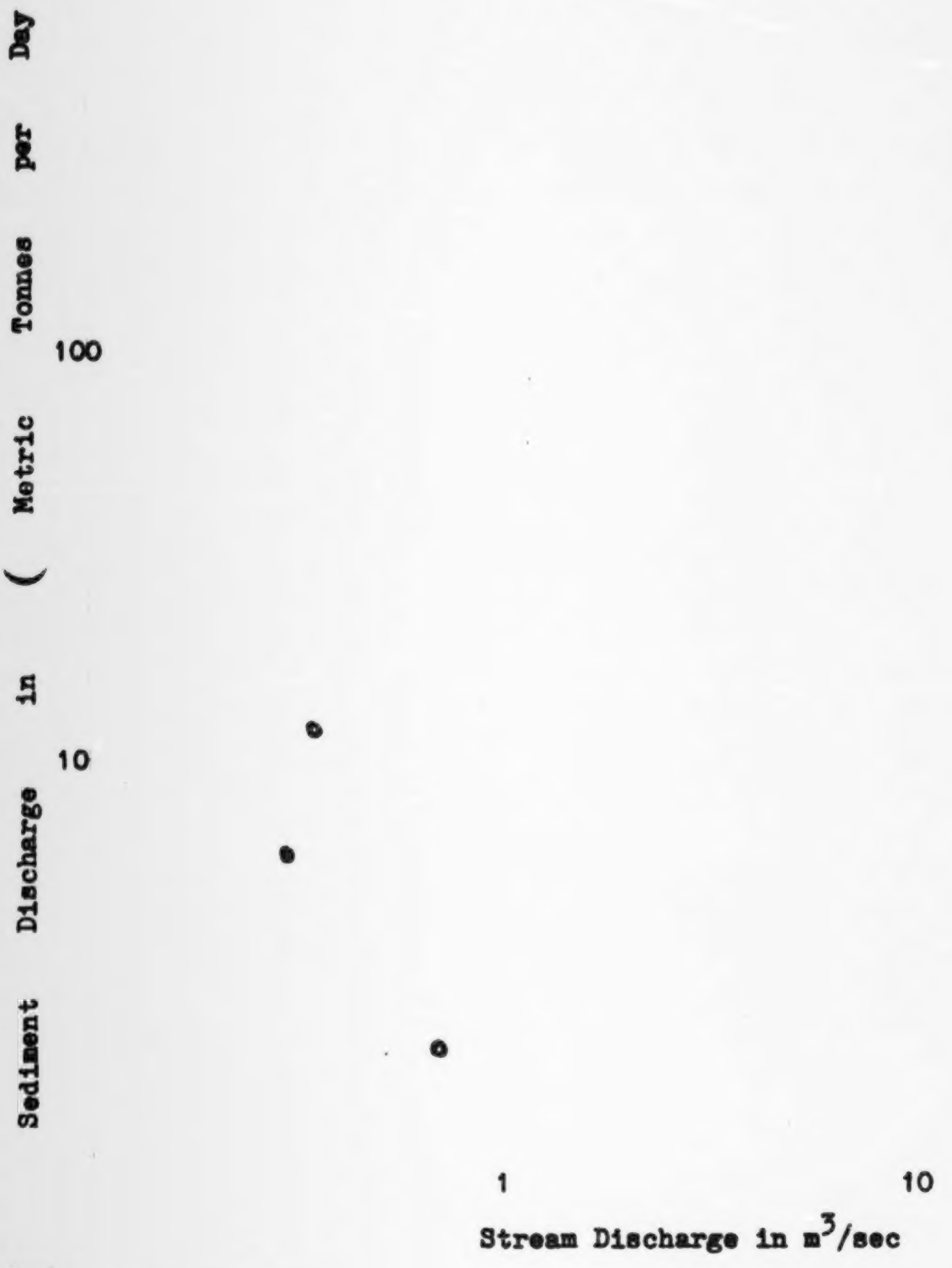


Figure 15: Sediment Discharge vs. Stream Discharge, Hanging Woman Creek at Birney, Montana
o Suspended sediment only

At several locations, notably the Birney section, no bedload movement was detected . For the small tributaries, bedload and suspended load are essentially the same at low flows, as the depth of the stream is often less than the orifice width of the Helley Smith sampler. However, the mesh opening of the sampler bag is .200 mm, so it is not surprising that little bedload is detected in the small streams. Most of the sediment in those streams is small enough to pass through the bag.

The samples are listed in chronologic order, and it is interesting to note the apparent effect of ice and frost action. Samples taken earlier in the spring typically have a higher percentage of bedload in the total load, even though the discharge of the river may be less.

Also of interest is the high percentage of silt-clay entering the stream by tributary. With the exception of one sample taken from Brown Creek, suspended samples contained more than 90% silt-clay. Little sand or gravel was detected moving in any of the tributaries, although the bed of Jack Creek indicates that some extremely coarse material was moving during peak runoff this spring. Unfortunately, the sample was taken at Jack Creek after the stream had fallen nearly 60 cm from its crest, and no movement was detected. In all cases, more samples will necessarily be taken before any substantial conclusions can be made concerning sediment movement.

Perhaps the most surprising results from the sampling program, are the relatively minor contributions in terms of both sediment and water discharge by two of the largest tributaries, Otter Creek and Hanging Woman Creek. While tributaries below the Viall section ran bankfull or over for a considerable time, neither Otter nor Hanging Woman Creek showed much increase in runoff. In both creeks, the dissolved load was much higher than the sediment load, and was much higher than any other streams sampled. This discrepancy may be due to differences in lithology. The surface materials along the lower basin are quite shaly, while the upper basin is more gravelly, with many areas underlain by highly fractured clinker.

The overburden materials in the Birney area are known to be highly saline. If the principle means of runoff in this area is by interflow or groundwater recharge, as it apparently is, it is not too surprising that these streams carry a high dissolved load and a low suspended load.

Results from the two-transect sampling method for the four major Tongue River sites are given in figures 14 through 17. Because sediment, particularly bedload, often moves in "slugs" or waves, additional data points will be needed before a given discharge can be said to be scouring or filling with any certainty. It is import-

Figure 16: Difference in sediment load between upstream and downstream transects, Orcutt Ranch Section.
+ indicates net increase at downstream transect
- indicates net loss at downstream transect.
o Suspended load, + Bedload

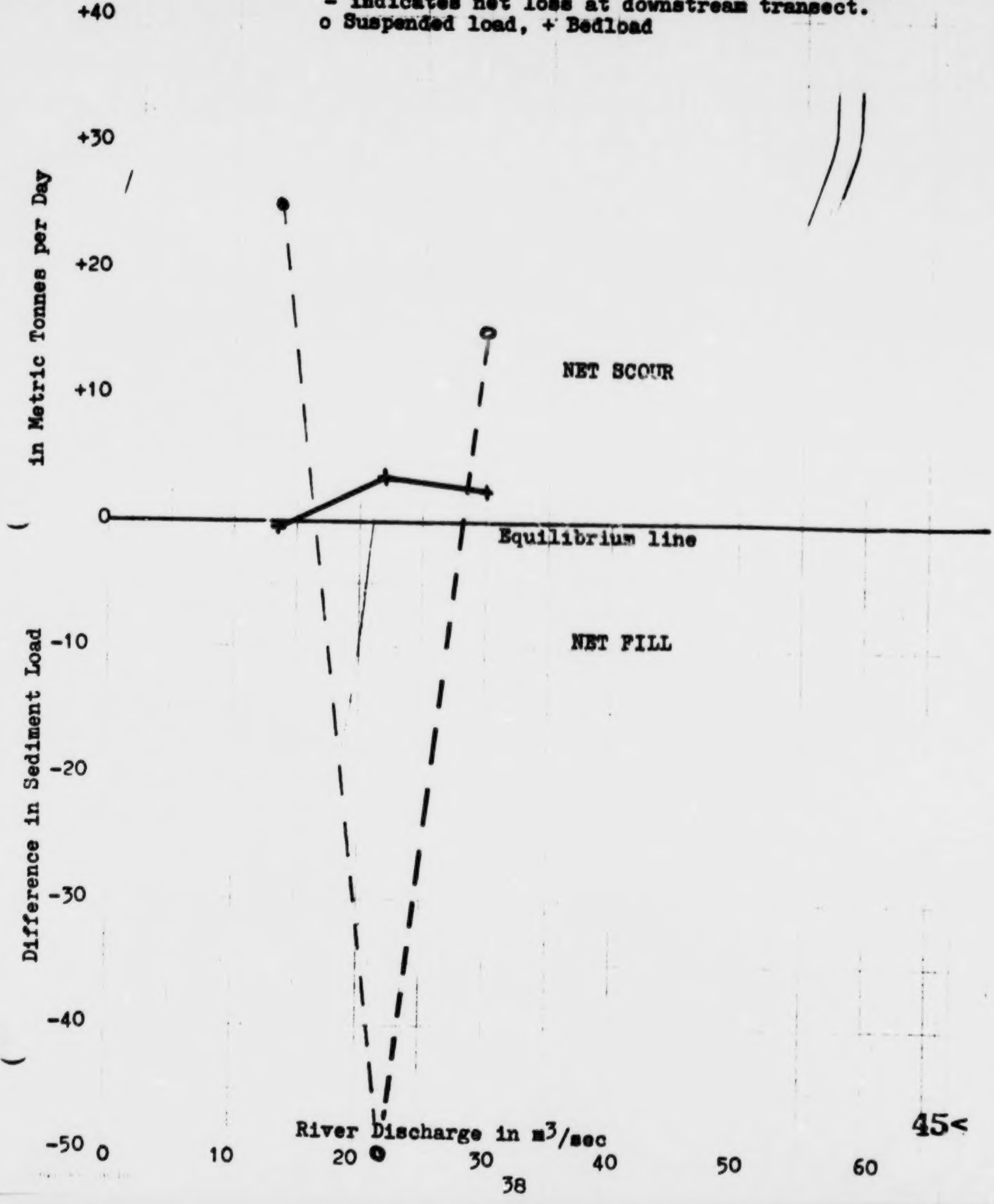


Figure 17 : Difference in sediment load between upstream and downstream transects, SH Ranch Section.
+ indicates net increase (scour) at downstream site
- indicates net loss (fill) at downstream site
o Suspended load, + Bedload

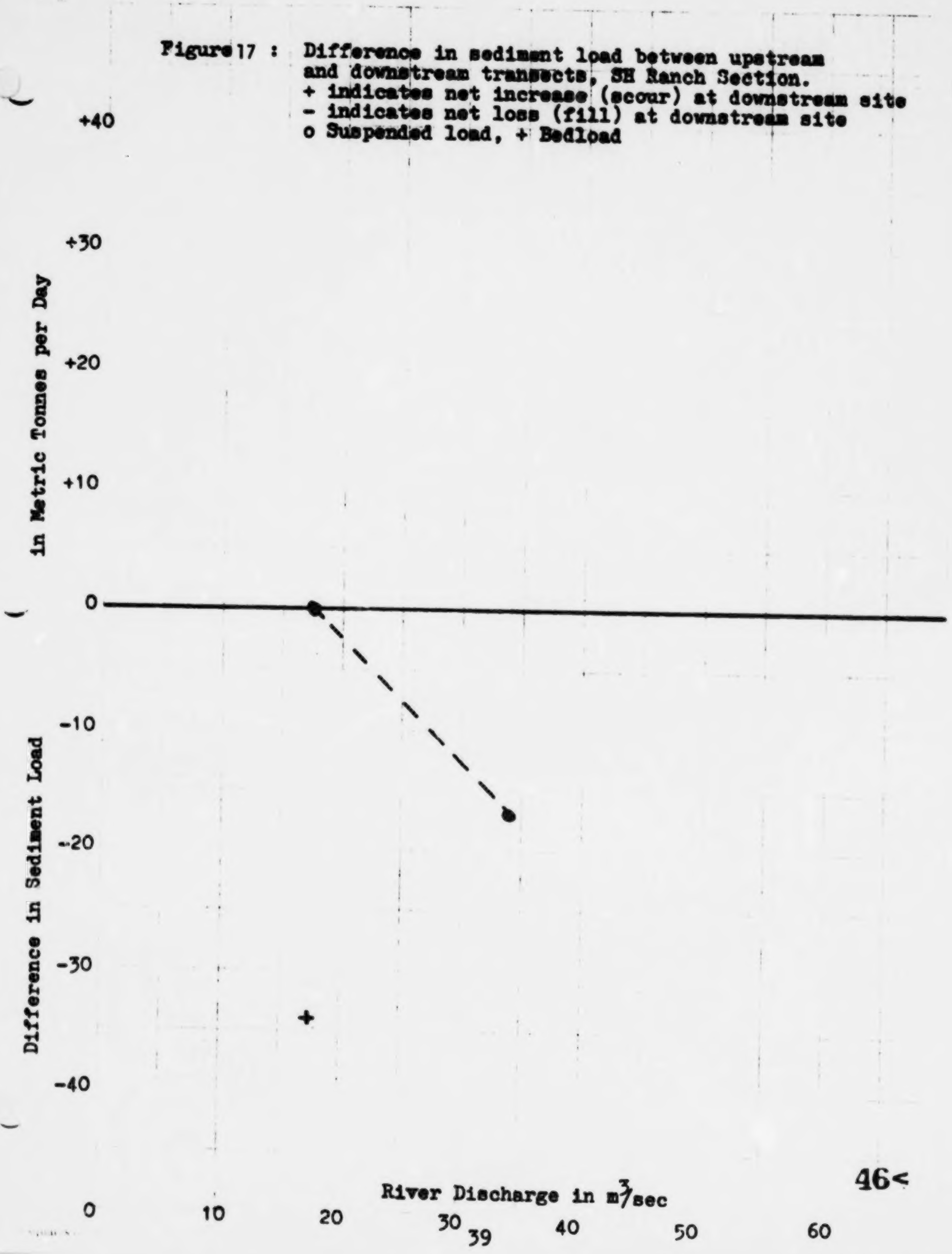


Figure 18: Difference in sediment load between upstream and downstream transects, Viall Ranch Section.
+ indicates net increase at downstream transect
- indicates net loss (fill) at downstream site
o suspended load, + Bedload

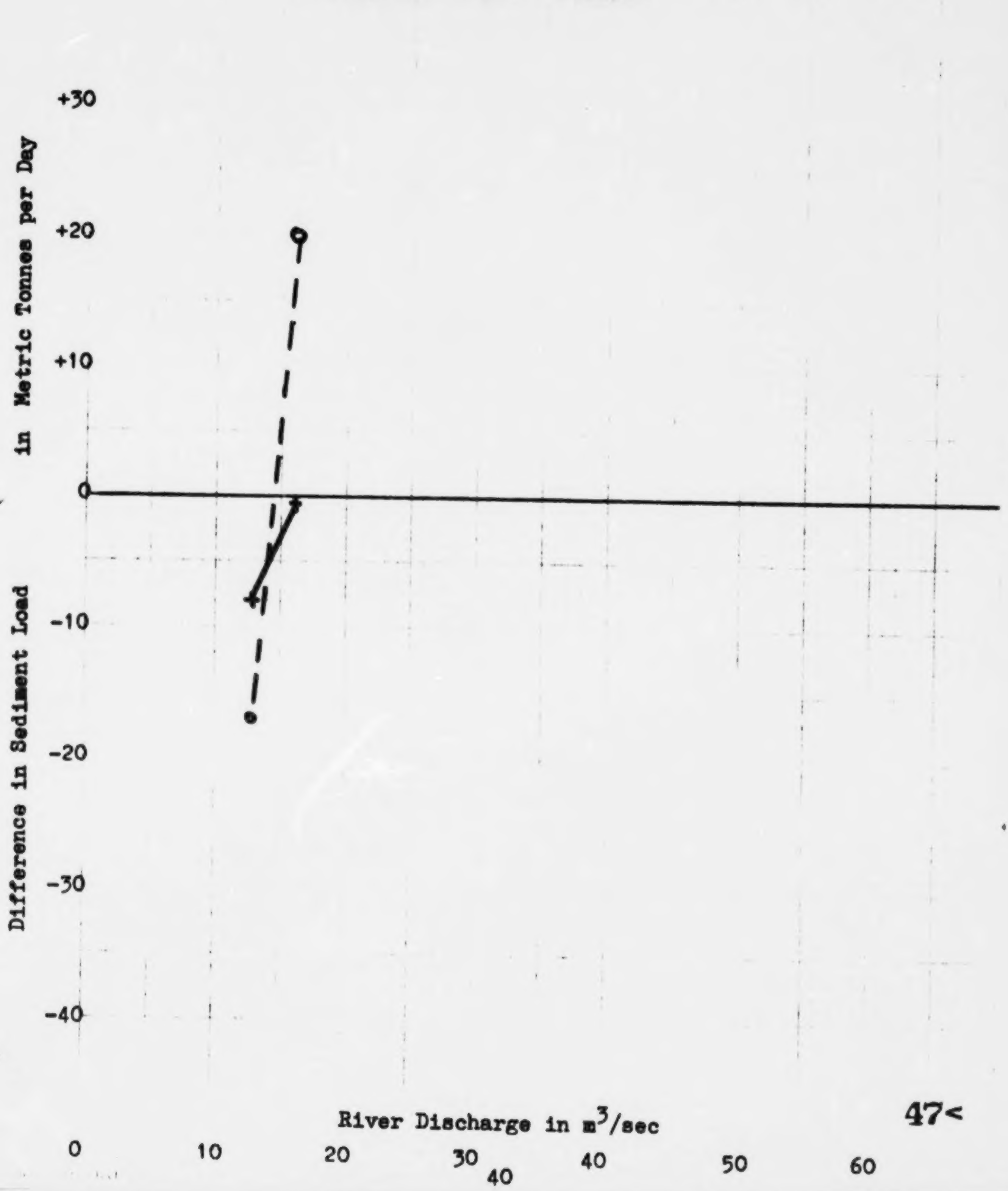
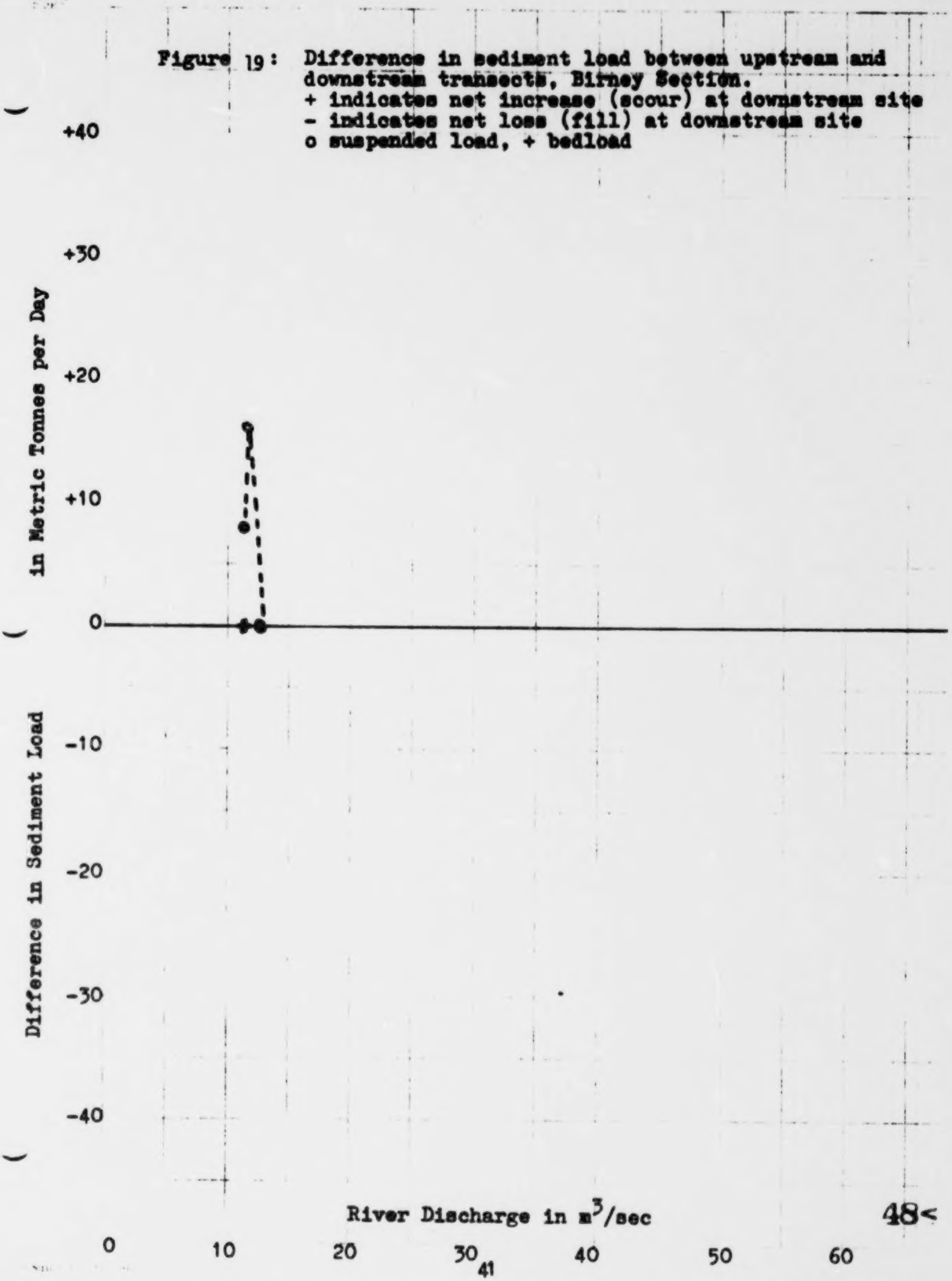


Figure 19: Difference in sediment load between upstream and downstream transects, Birney Section.
+ indicates net increase (scour) at downstream site
- indicates net loss (fill) at downstream site
o suspended load, + bedload



ant to note however, that while the suspended fraction of the total load accounts for most of the sediment movement, most of that fraction at all discharges measured, was wash load. When the difference between upstream and downstream sites is considered, the bedload difference is of the same or greater magnitude than the suspended load in many instances. Therefore, even though the bedload accounts for only a minor fraction of the total sediment load carried by the river, it may be the more important fraction where the aquatic community is concerned.

SUMMARY

Flow criteria for the recommendation of minimum streamflows during the rearing period have been established, using the stonecat (*Noturus flavus*) as an indicator species. The criteria include depths from 30 to 60 cm, and velocities from 45 to 90 cm/sec over areas of medium to large cobble.

Four hydrologic mapping sections were established over areas of known stonecat concentrations. These sections were widely separated over the length of the Tongue River. Mapping of the areas has not proceeded far enough to delineate the optimum or recommended minimum streamflows. However, based on completed maps, it appears that the optimum flow lies in the range of 11 to 17 m^3/sec. The recommended minimum flow would then lie in the range of 8.3 to 12.7 m^3/sec.

First year results from the study of river ice indicate that reduced streamflows may result in an increased thickness of the surface ice sheet. A moderate inverse correlation was found between the current velocity and ice thickness. This suggests that reduced current velocity caused by lowered streamflow could result in a thicker ice cover. Coupled with reduced depth of water, extensive areas of the river may be frozen to the streambed. Reduced stream discharge during the winter and during spring break-up may cause the incidence of ice jamming to increase. This presents a potential threat not only to the aquatic community, but also to man-made structures along the river.

Sediment samples are being taken to determine whether or not a recommended flow based on fishery requirements will be sufficient for the transport of sediment through the system. More sampling is required before this type of judgement can be made.

It was determined that the suspended load comprises most of the total load transported by the river, for the discharges measured. However, most of the suspended load is "wash load" composed of very fine particles. In terms of net gain or loss of sediment moving across a section of streambed, the bedload is frequently of greater importance than is the suspended load. Because bedload particles are uniformly larger than suspended particles, bedload motion is of great importance to the aquatic community.

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APPENDIX A

ICE MEASUREMENT DATA FOR THE TONGUE RIVER
JANUARY-FEBRUARY, 1975

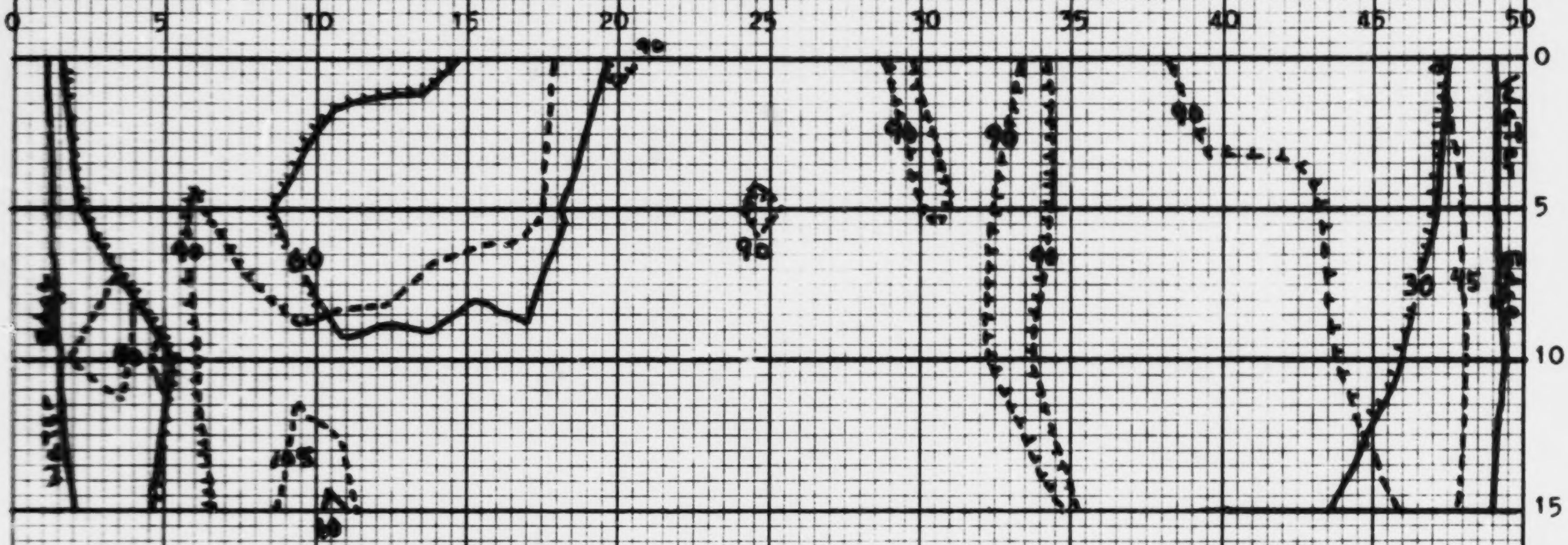
Section	Velocity cm/sec	Depth cm	Ice Thickness cm	Envelope Thickness cm
Ft. Keogh I	37	32	22	10
	11	27	14	13
	23	34	10	24
	43	44	21	23
(1/14/75)	56	60	22	38
	27	34	31	3
	0	27	25	2
	61	30	5	25
	25	39	27	12
	52	45	25	20
	54	60	27	33
Ft. Keogh II*				
		49	44	25
(2/21/75)		54	48	10
		51	47	11
		50	53	10
Woodard Ranch				
	30	34	24	10
(1/20/75)	51	34	18	16
	90	45	9	36
	35	33	20	13
	18	32	24	8
	14	22	20	2
	58	33	0	33
	135	33	0	33
	63	45	0	45
	0	25	25	0
	0	38	17	21
	0	40	15	25
	0	40	36	4
	0	30	29	1
	28	30	20	10
SH Ranch		93	50	43
		96	47	49
		75	50	25
		66	47	19
		68	47	21
		84	56	27
		87	56	31
		96	58	38
		87	55	32
		79	44	35

*Surface of Ice higher than hydrostatic head.

Section	Velocity cm/sec	Depth cm	Ice Thickness cm	Envelope Thickness cm
SH Ranch		63	35	28
		71	37	34
		79	38	41
Viall Ranch	57	41	6**	35
	68	61	23	38
(2/20/75)	64	72	30	42
	34	60	27	33
	44	65	36	29
	55	50	23	27
		46	35	11
		47	31	16
		39	28	11
		45	15	30
Birney	13	31	6**	25
	13	44	28	16
	38	48	3	45
	80	45	0	45
	86	33	9	24
	59	37	22	15
	68	43	18	25
	22	53	33	20
	37	45	28	17
	28	49	35	14
	18	42	36	6
	9	28	20	8

** Influenced by groundwater.

APPENDIX B
HYDROLOGIC CONTOUR MAPS
TONGUE RIVER STUDY SITES



Composite map showing areas meeting criteria of depth and velocity

Orcutt Ranch Section

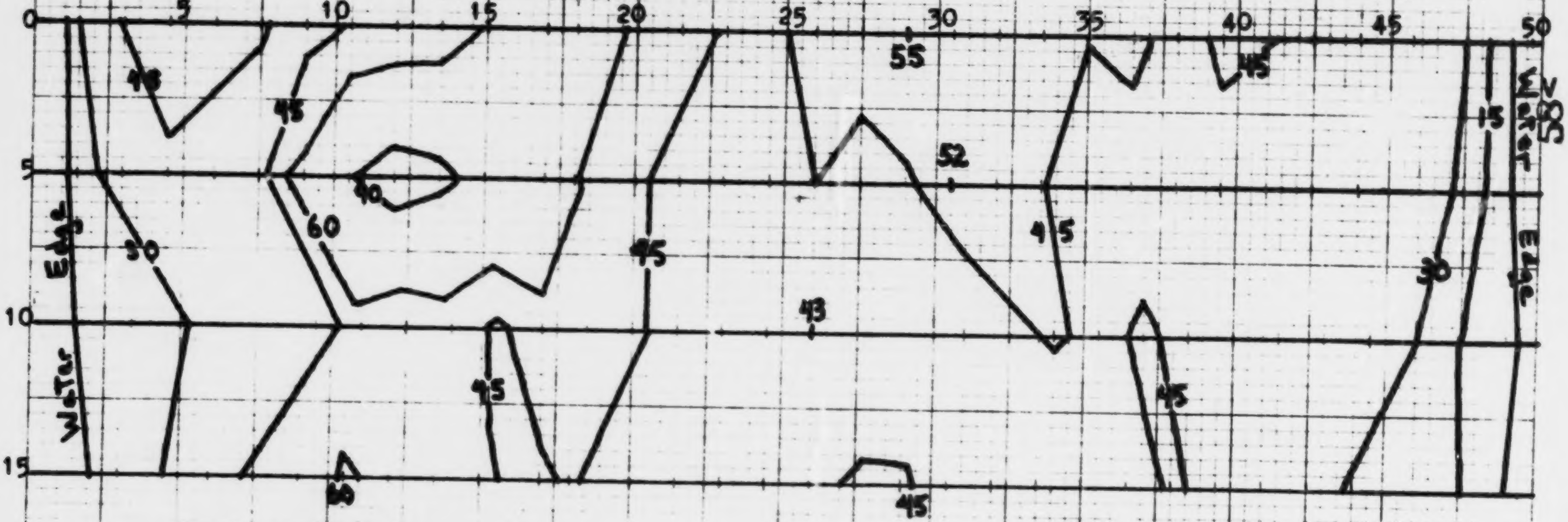
$Q = 19.0\ m^3/sec = 670\ cfs$

Total surface area = 716 m^2

Total area meeting criteria = 145 m^2

Percent total meeting criteria = 20%

K+E 10 X 10 TO THE INCH 46 0703
KEUFFEL & ESSER CO.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5
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20
25
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40
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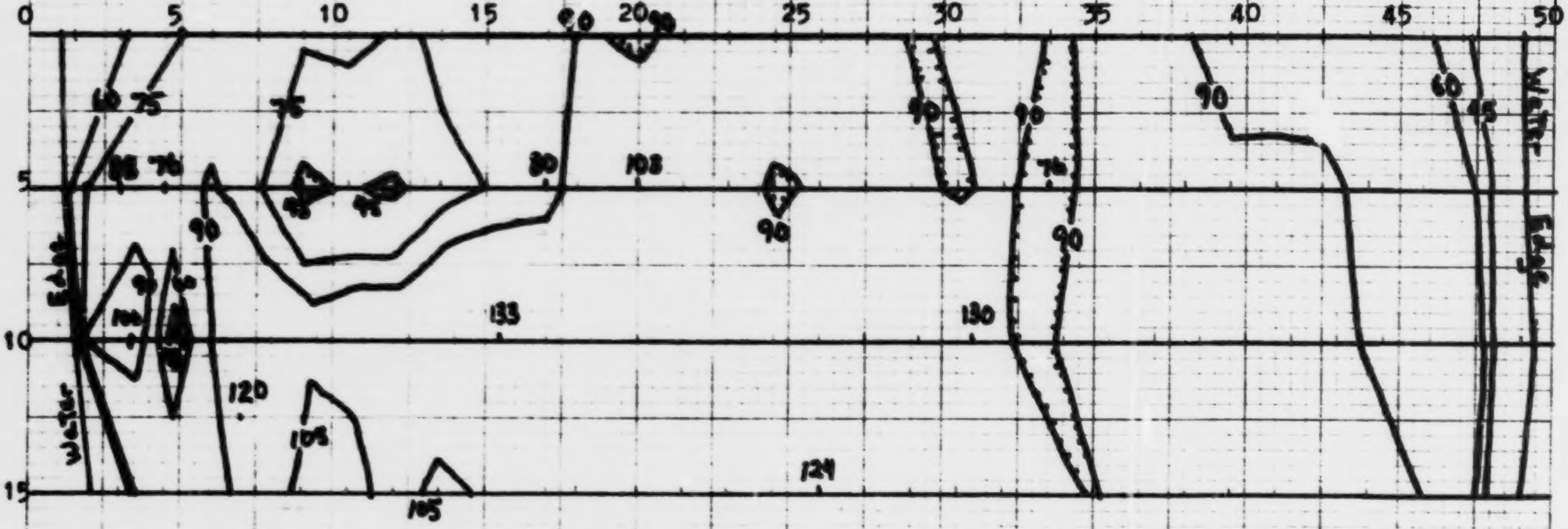
5
10
15
Water Edge
Water Edge
48
45
30
60
40
45
45
60
55
52
43
45
45
45
45
45
45
30
15

Depth Contour Map

Orcutt Ranch Section

Q = 19.0 m^3/sec = 670 cfs

10 Squares to the Inch



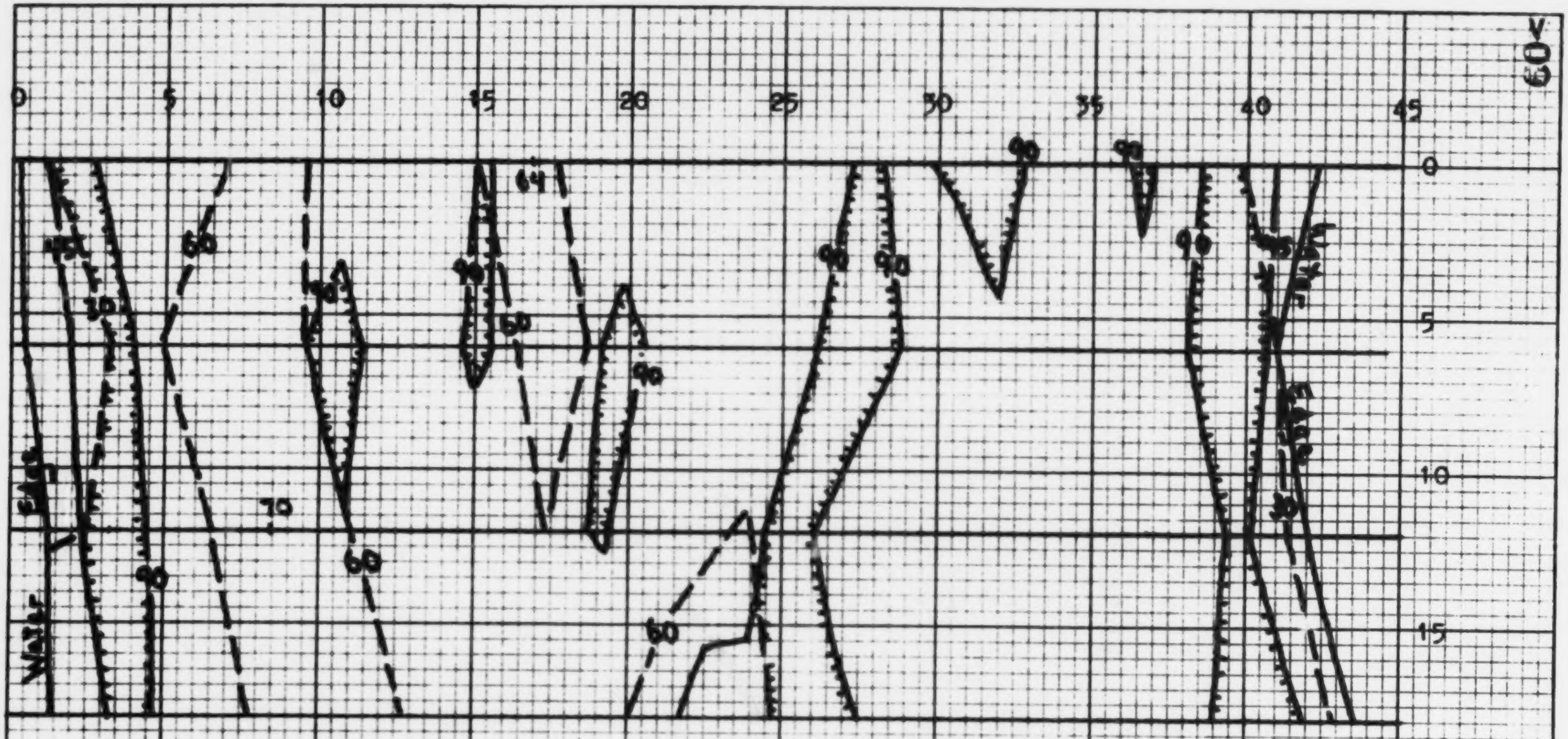
Velocity Contour Map

Orcutt Ranch Section

$Q = 19.0\ m^3/sec = 670\ cfs$

Velocities in cm/sec, units of length in meters

10 Squares to the Inch



Composite Map Showing Depth and Velocity Criteria

Viall Ranch Section

Q = 19.4 m^3/sec = 686

Total Water Surface Area = 739 m^2

Total Area Meeting Criteria = 116 m^2

Percent Total Meeting Criteria = 16%

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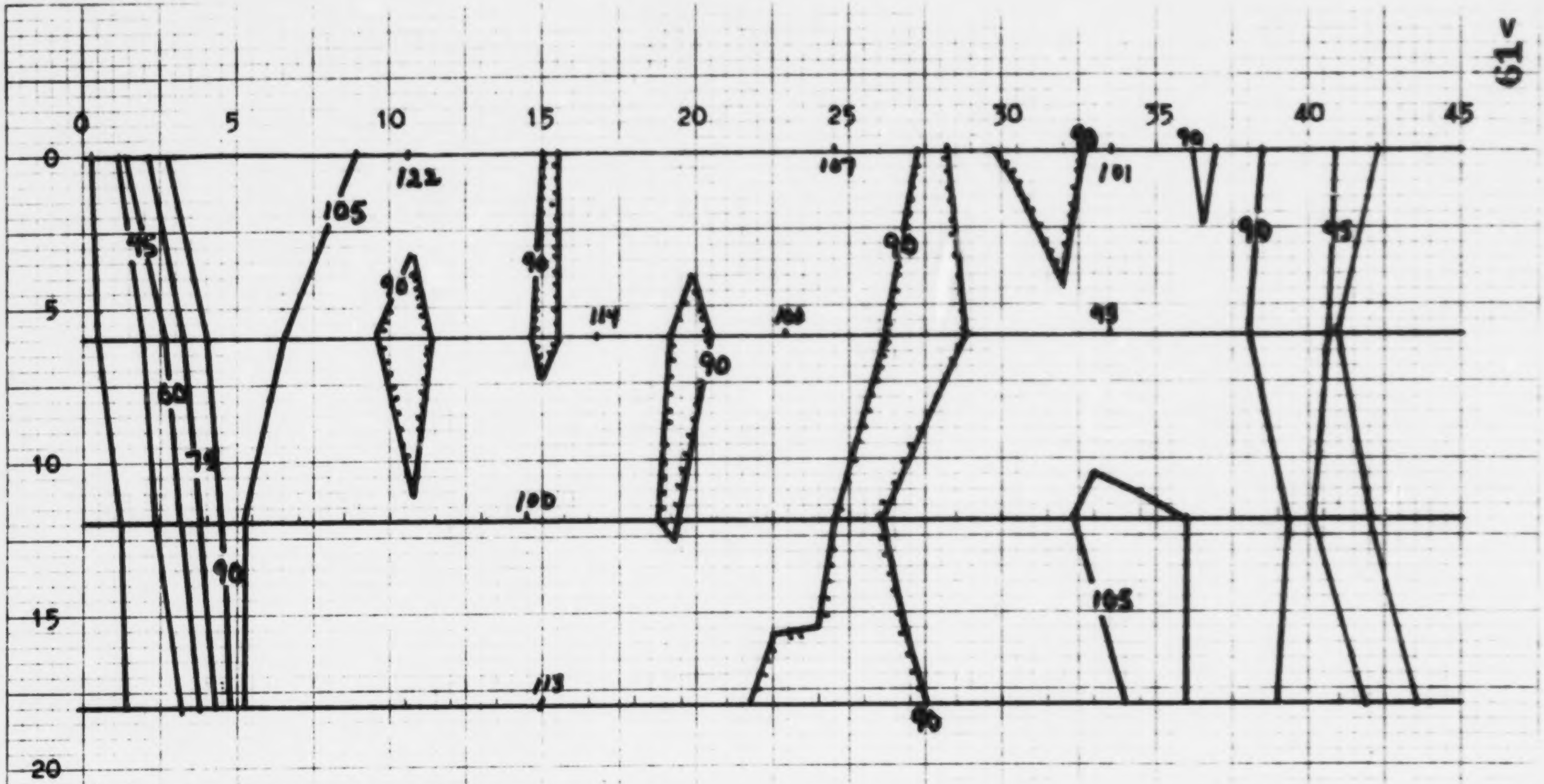
KEUFFEL & ESSER CO.

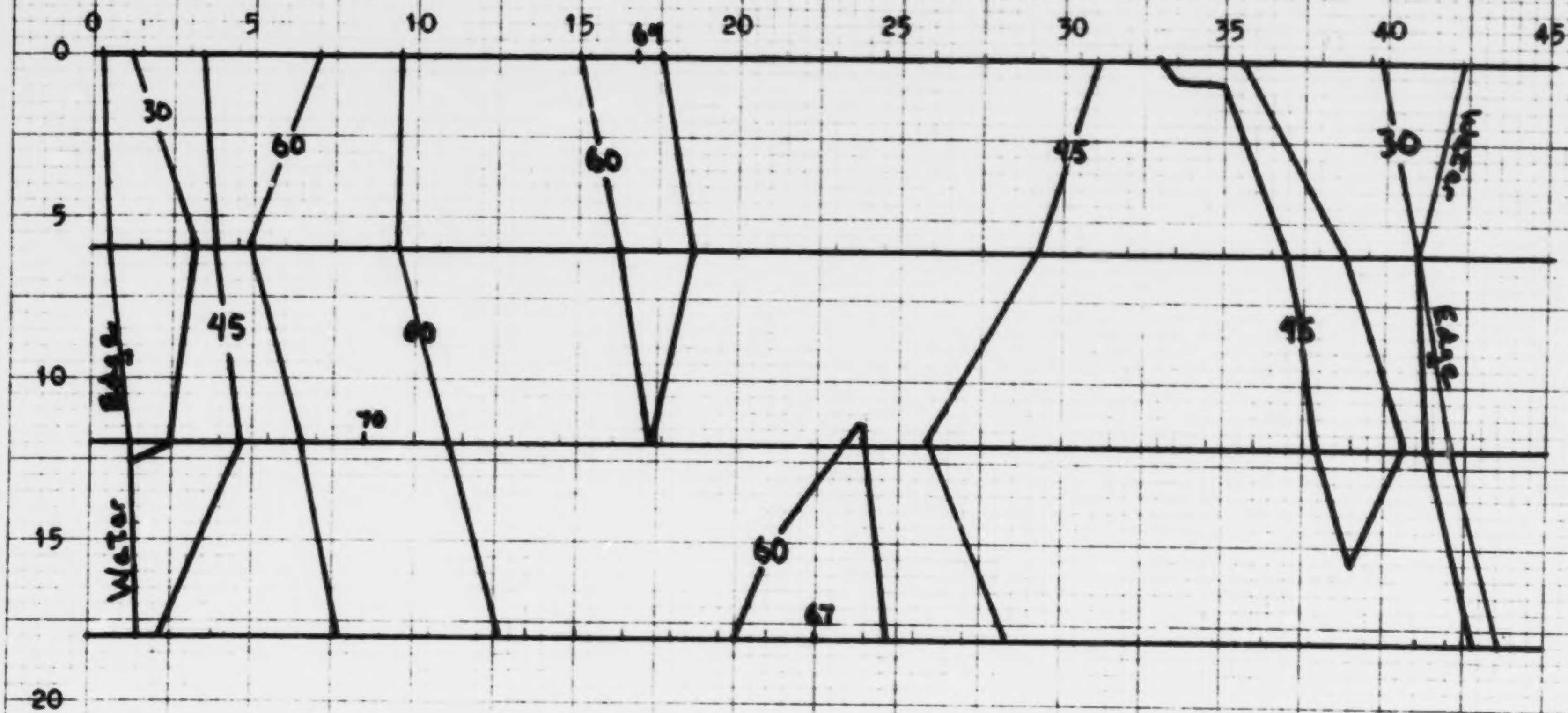


Velocity Contour Map

Viall Ranch Section

$Q = 19.4\ m^3/sec = 686\ cfs$

Velocities in cm/sec, units of length in meters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10
15
20
25
30
35
40
45
0
5
10
15
20
Water Edge
Water Edge
30
45
60
60
70
60
69
60
67
45
45
30

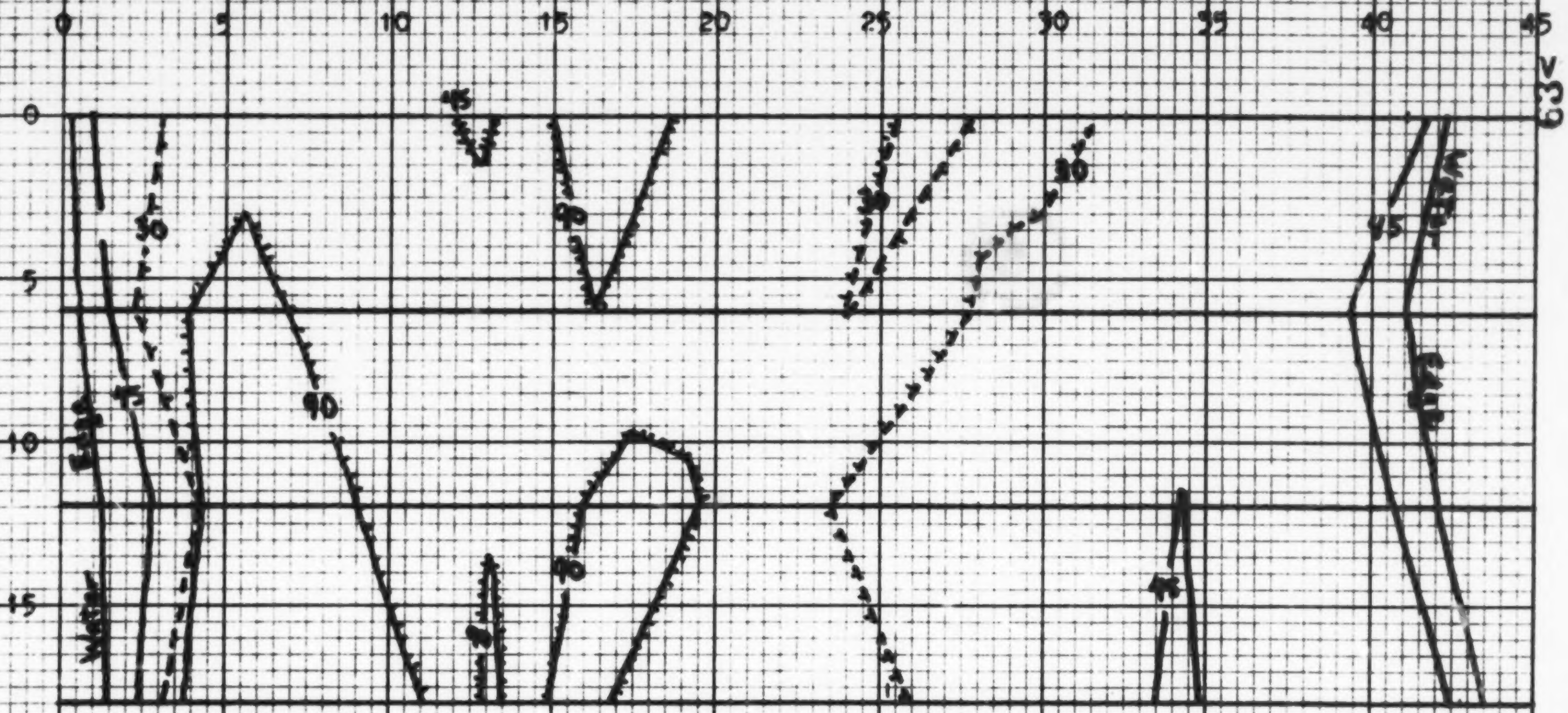
Depth Contour Map

Viall Ranch Section

Q = 19.4 m^3/sec = 686 cfs

Depths in cm, units of length in meters

10 Squares to the Inch



Composite Map Showing Areas Meeting Depth and Velocity Criteria

Viall Ranch Section

Q = 11.3 m^3/sec = 398 cfs

Total Water Surface Area; 739 m^2

Total Area Meeting Criteria = 338 m^2

Percent Total Meeting Criteria = 46%

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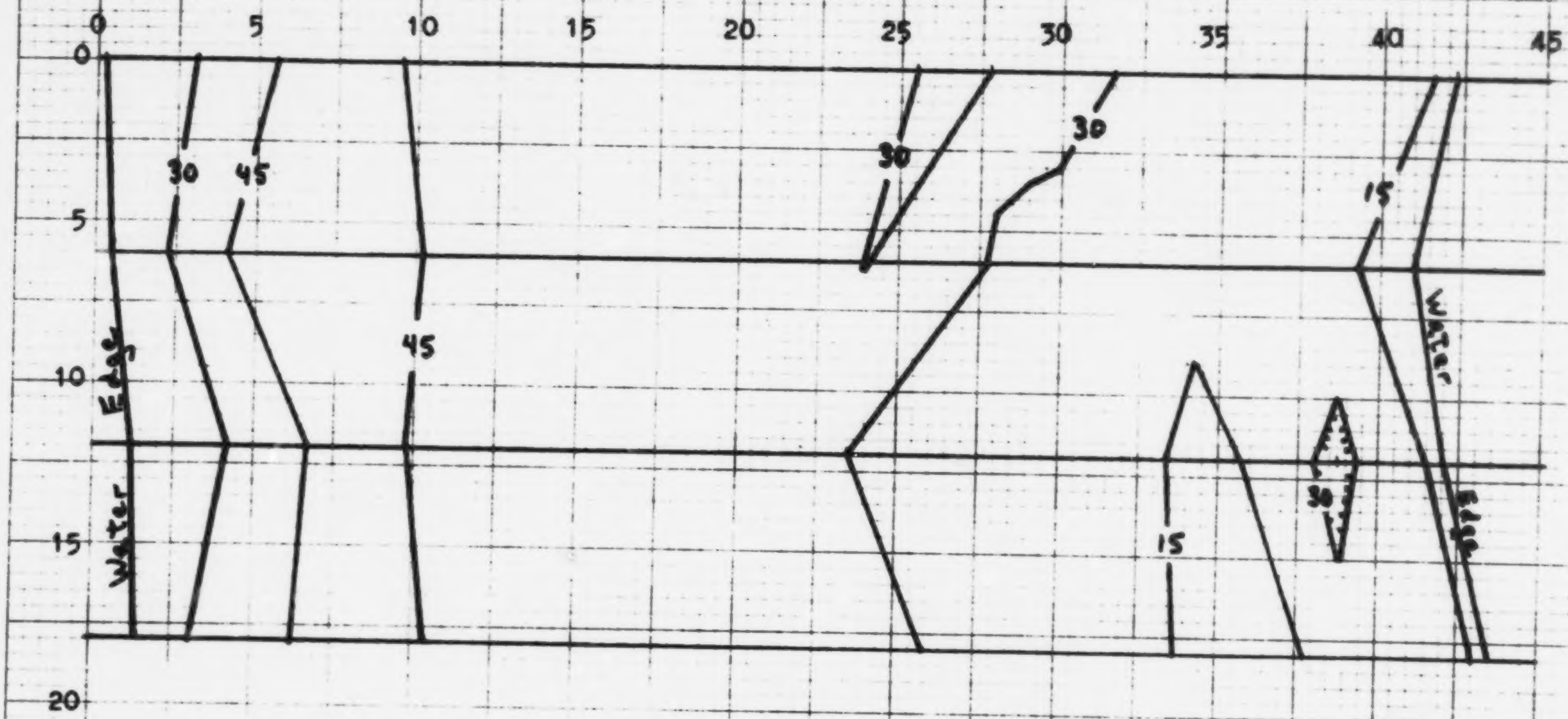
KEUFFEL & ESSER CO.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15
15
30
Water Edge
Water Edge

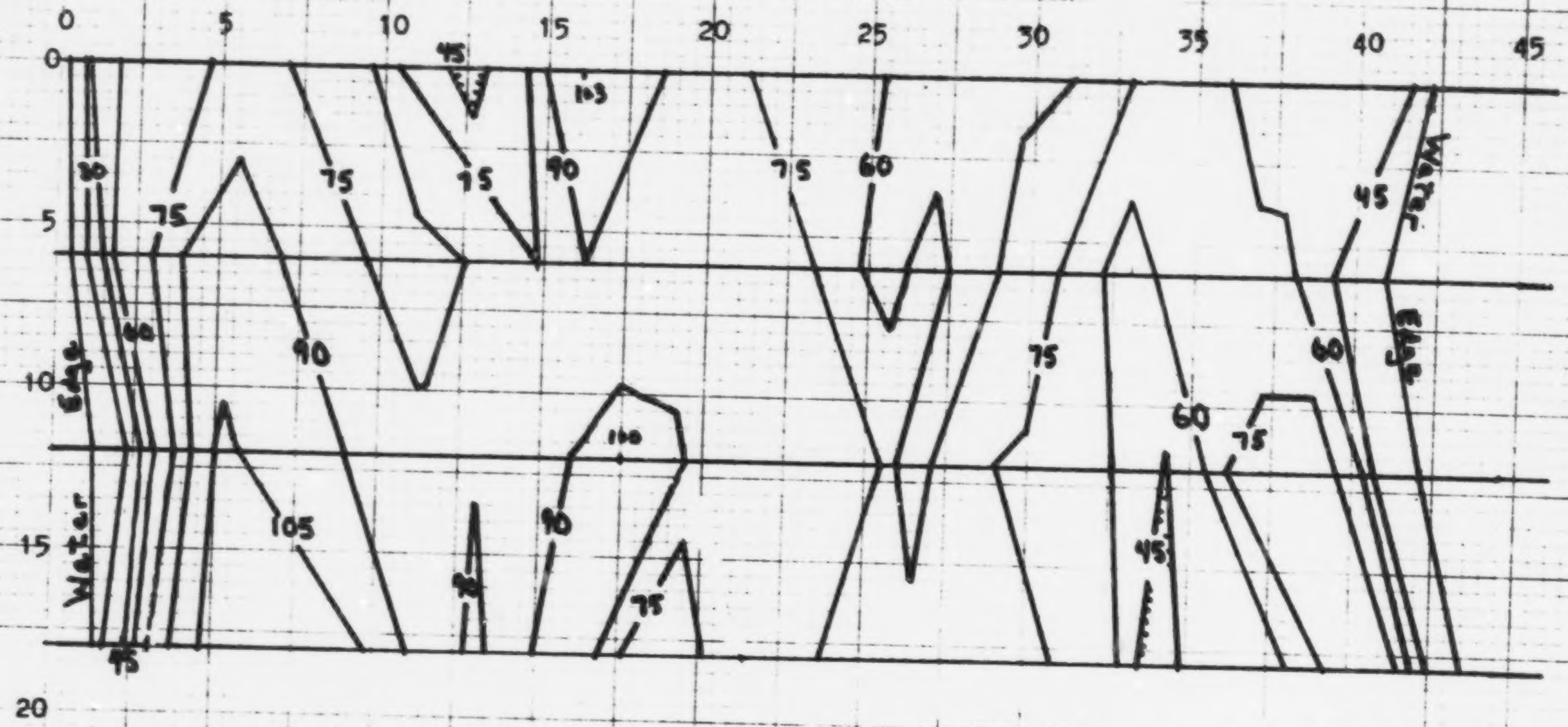
Depth Contour Map

Viall Ranch Section

Q = 11.3 m^3/sec = 398 cfs

Depths in cm, units of length in meters

10 Squares to the Inch

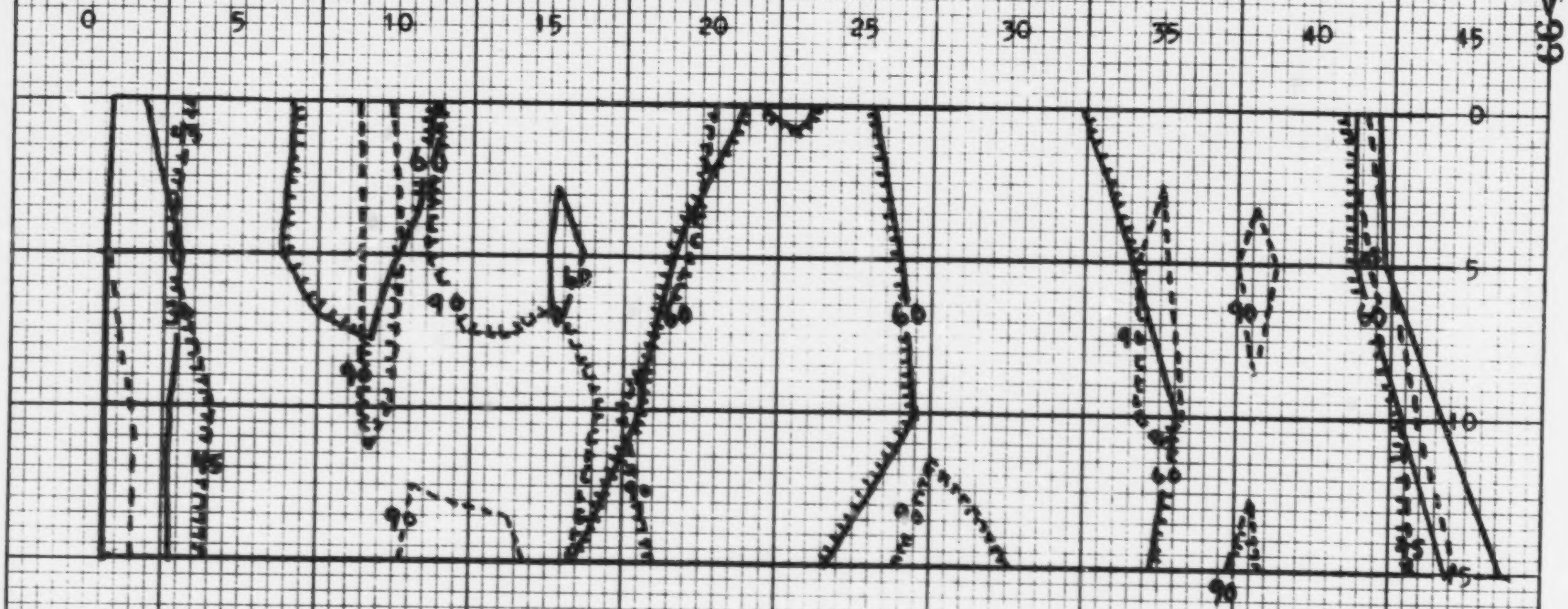


Velocity Contour Map

Viall Ranch Section

Q = 11.3 m^3/sec = 398 cfs

Velocities in cm/sec, units of length in meters


0
5
10
15
20
25
30
35
40
45
0
5
10
15
60
90
45

Composite map showing areas meeting depth and velocity criteria

SH Ranch Section. Q = 19.2 m^3/sec = 68C cfs

Total Wetted Area = 614 m^2

Total area meeting criteria = 231 m^2

Percent total meeting criteria = 58%

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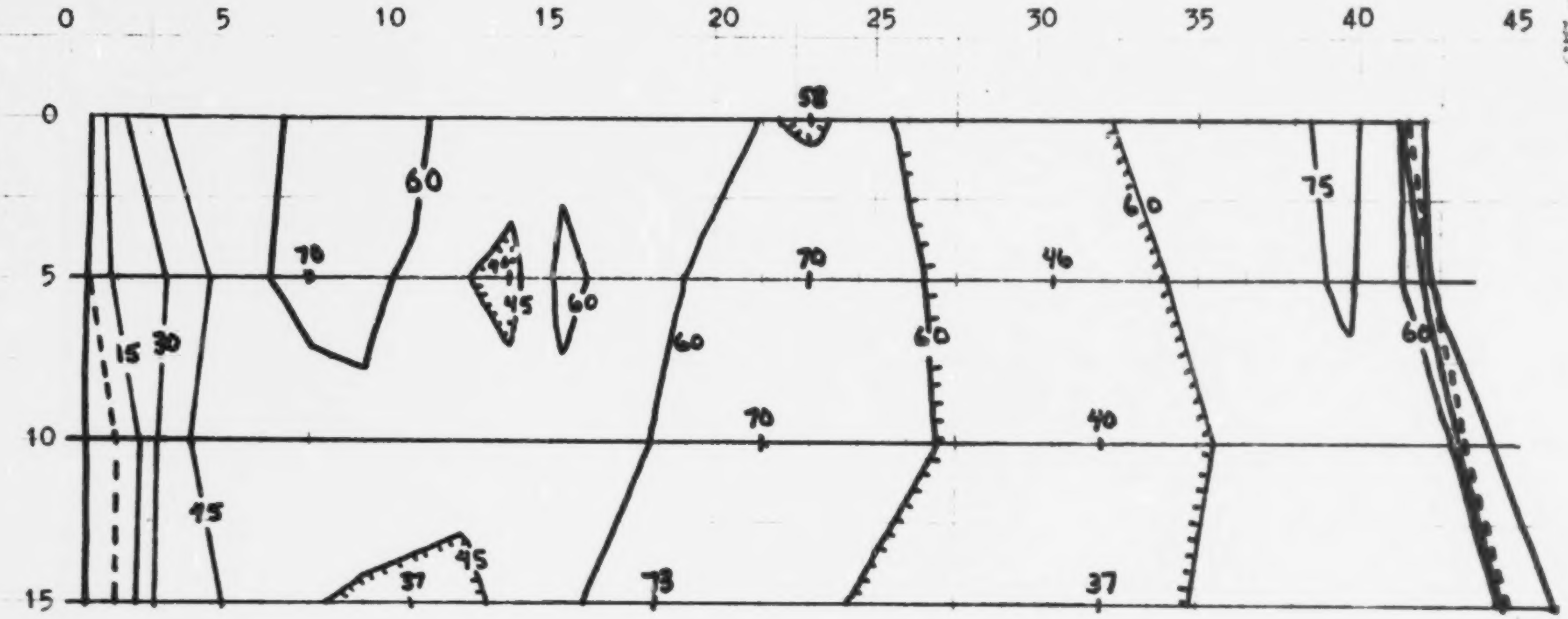
7 X 10 INCHES
KEUFFEL & ESSER CO.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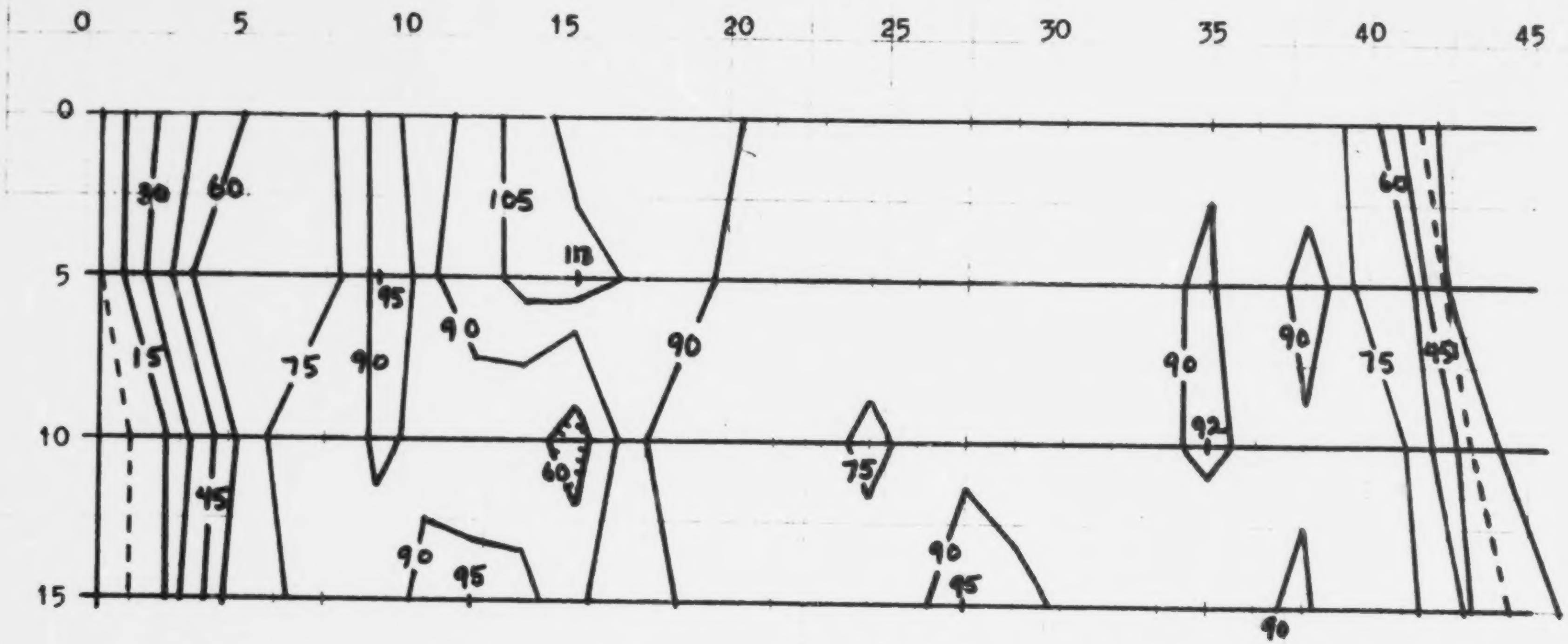
30
45
37
45
58
70
60
70
73
60
46
40
37
60
75
60

Depth Contour Map

SH Ranch Section

Q = 19.2 m^3/sec = 680 cfs

Depths in cm, units of length in meters

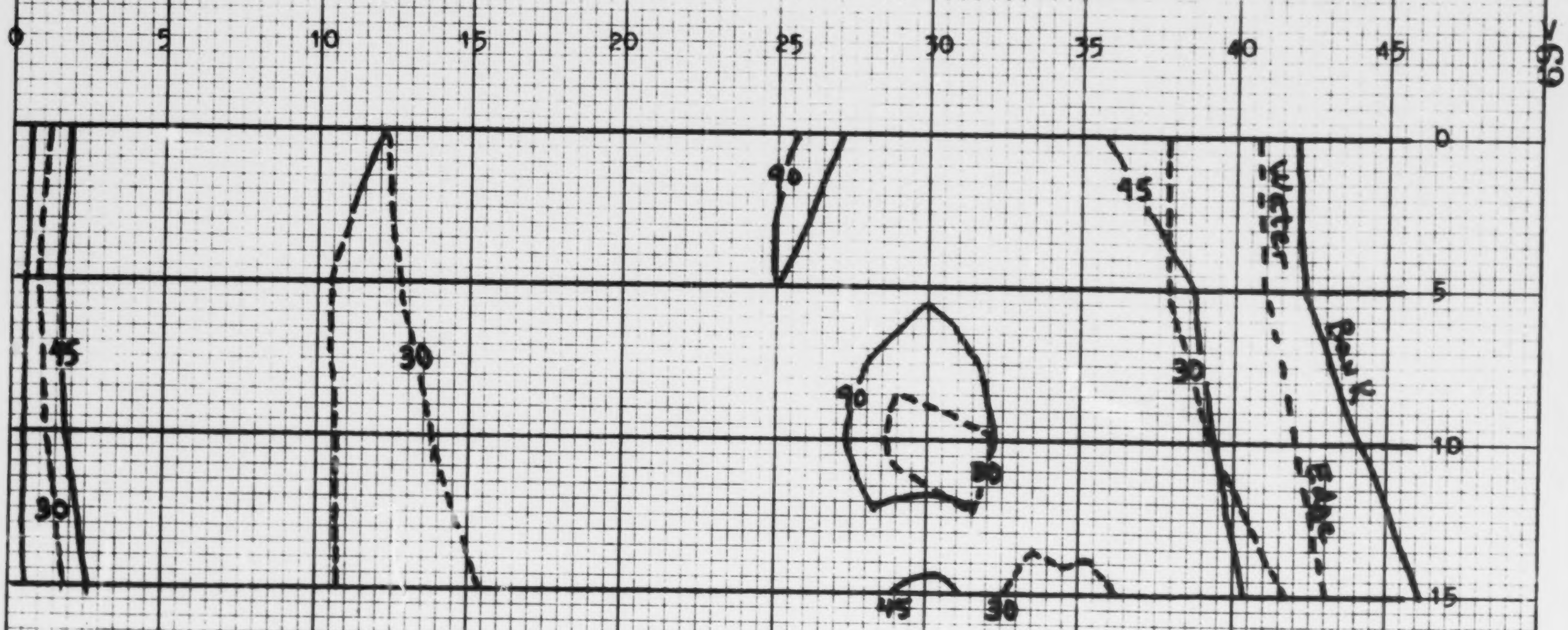


Velocity Contour Map

SH Ranch Section

Q = 19.2 m^3/sec = 680 cfs

Velocities in cm/sec, units of length in meters



Composite map showing areas meeting depth and velocity criteria.

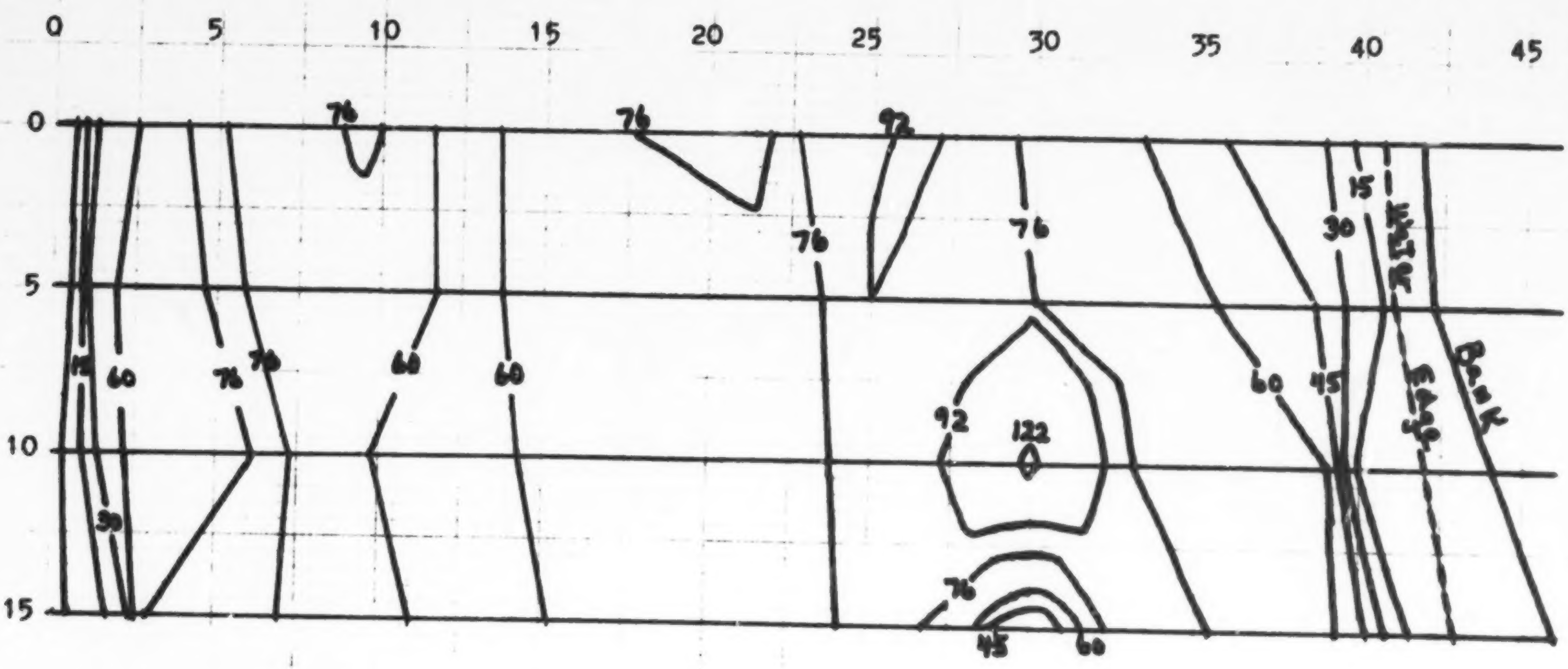
9H Ranch Section. $Q = 11.3\ m^3/sec$ = 400 cfs

Total wetted area = $614\ m^2$

Total area meeting criteria = $474\ m^2$

Percent total meeting criteria = 77%

K+E 10 X 10 TO THE INCH 46 0703
KEUFFEL & ESSER CO.

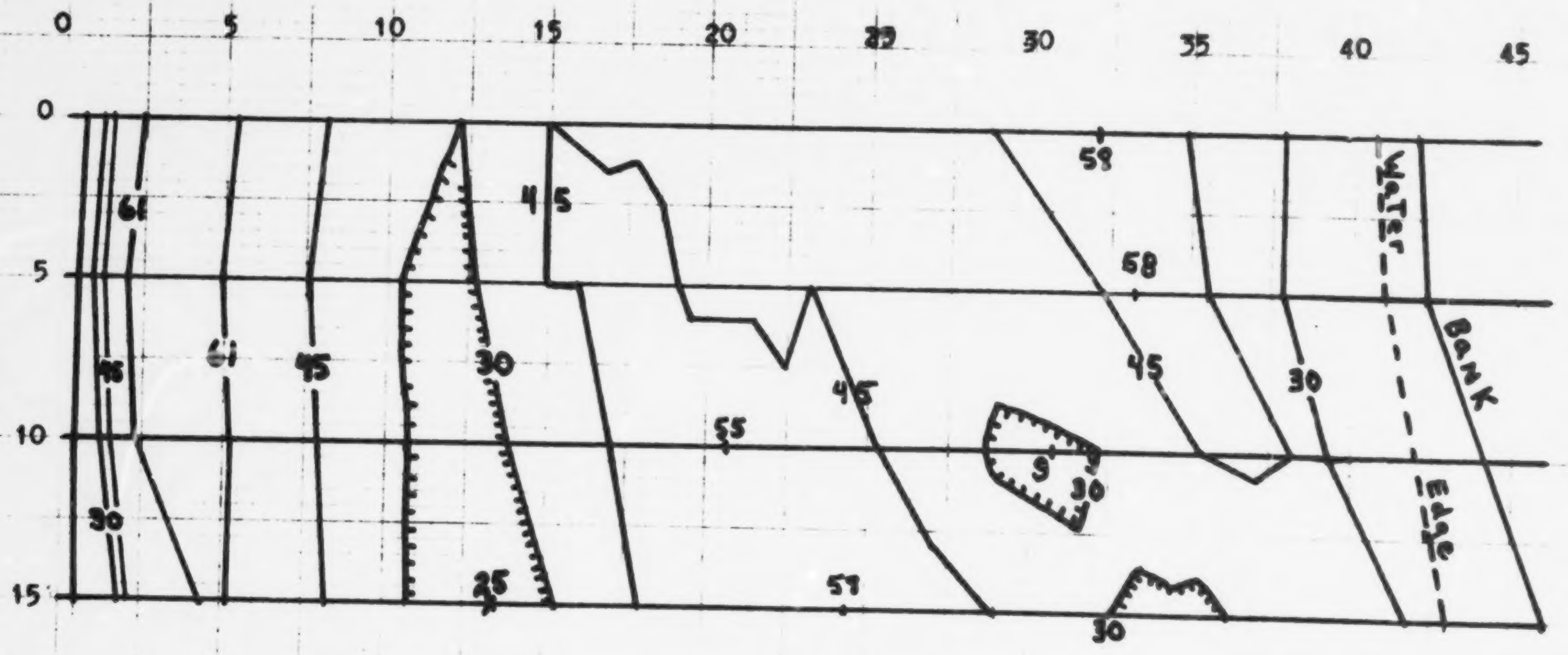


Velocity Contour Map.

SH Ranch Section

Q = 11.3 m^3/sec = 400 cfs

Velocities in cm/sec; Unit of Length in Meters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25
55
45
57
58
58
45
9
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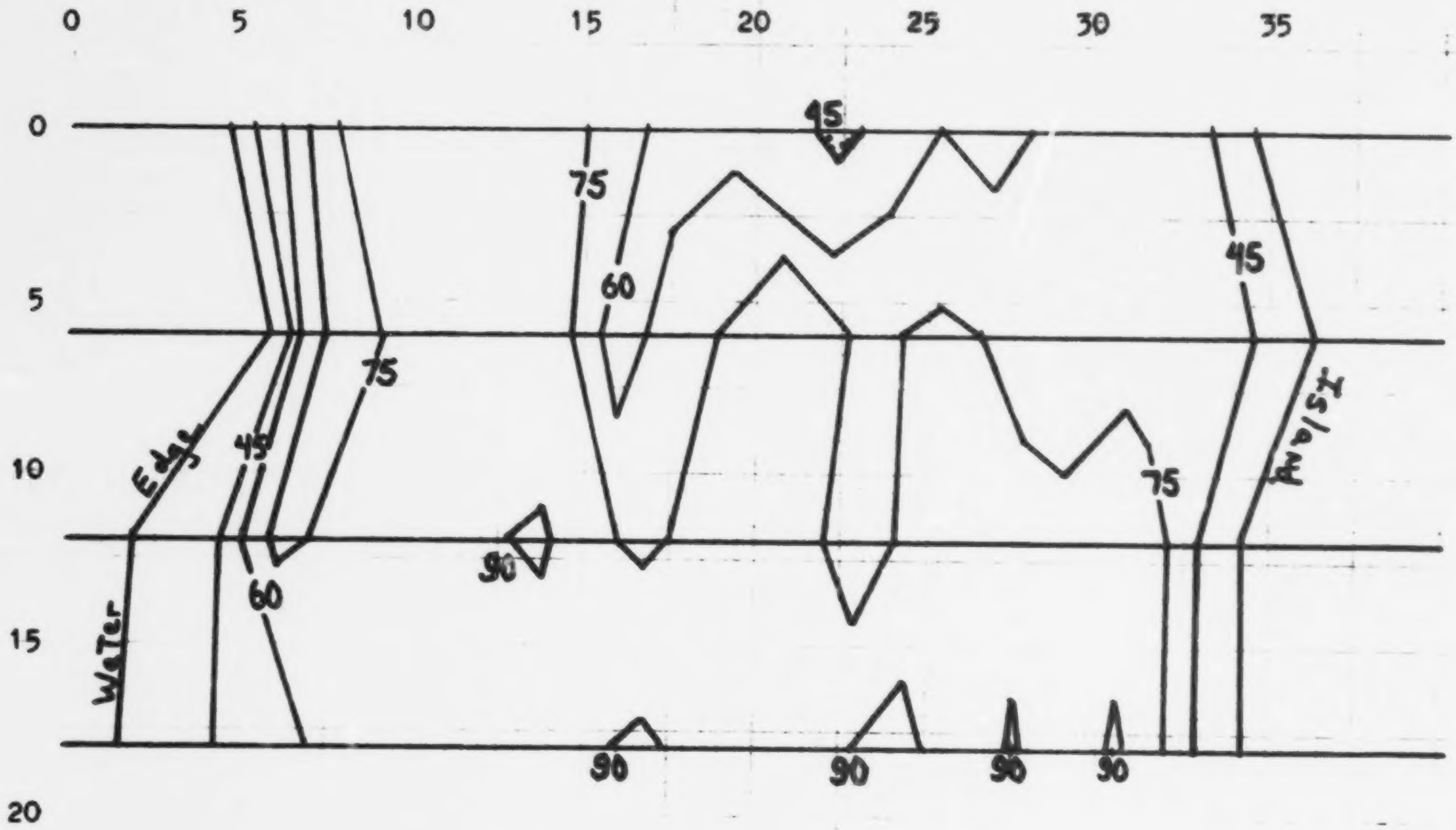
30
Water
Edge
Bank

Depth Contour Map

SH Ranch Section

Q = 11.3 m^3/sec = 400 cfs

Depths in cm, units of length in meters

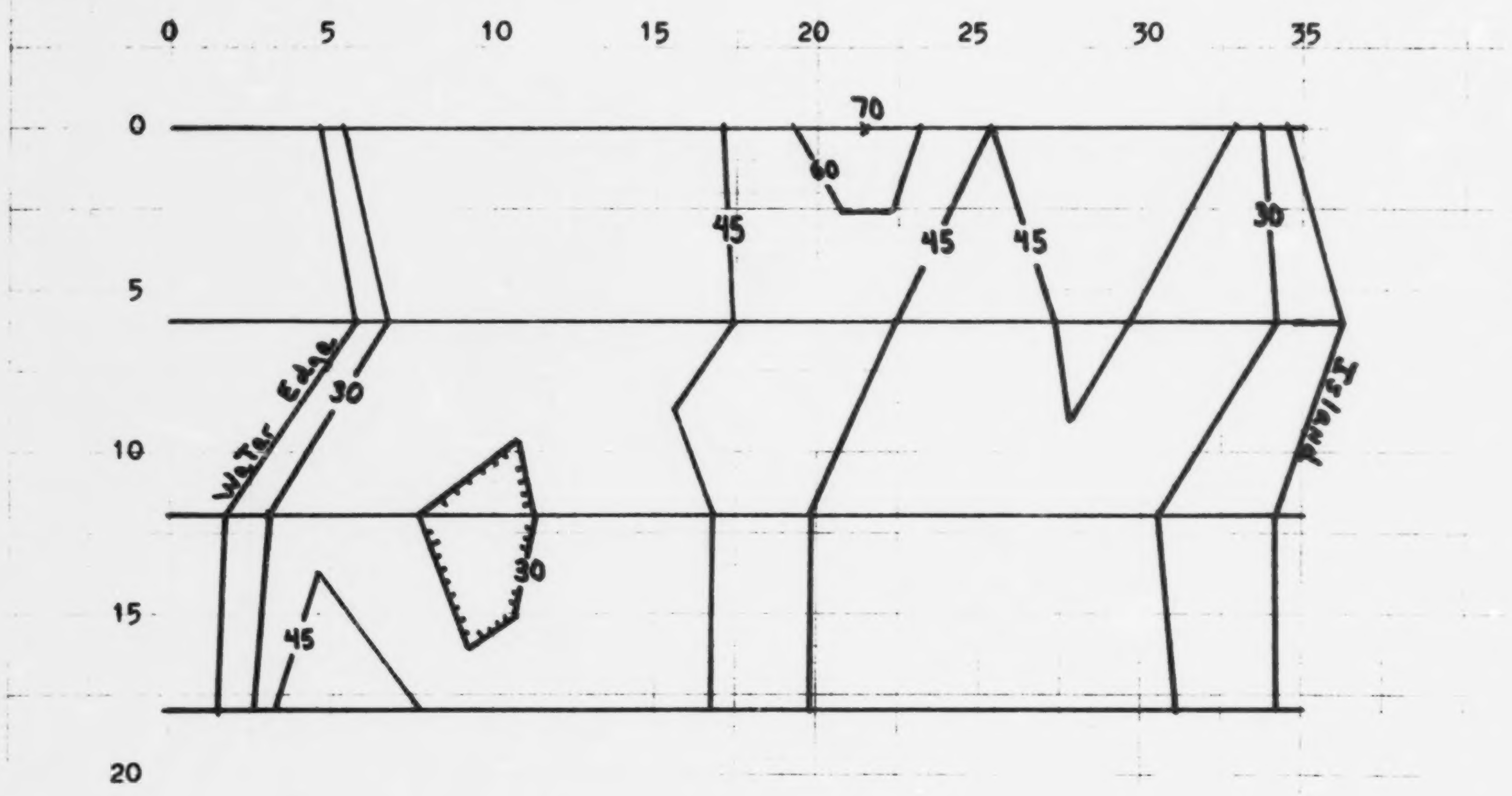


Velocity Contour Map

Birney Section, Right Channel facing Downstream

Total Q = 15.7 m^3/sec = 555 cfs

Velocities in cm/sec, Units of length in meters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45
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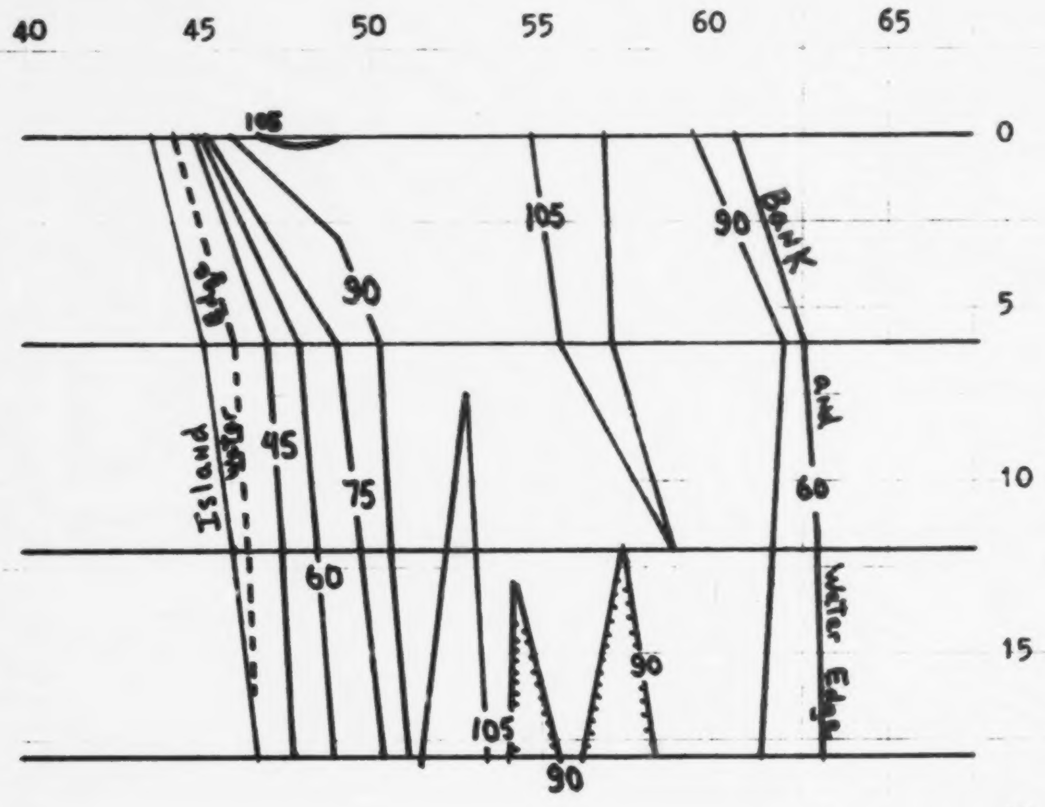
30
45
30
Water Edge
Island

Depth Contour Map

Birney Section, Right Channel Facing Downstream

Q = 15.7 m^3/sec = 555 cfs

Depths in cm, units of length in meters

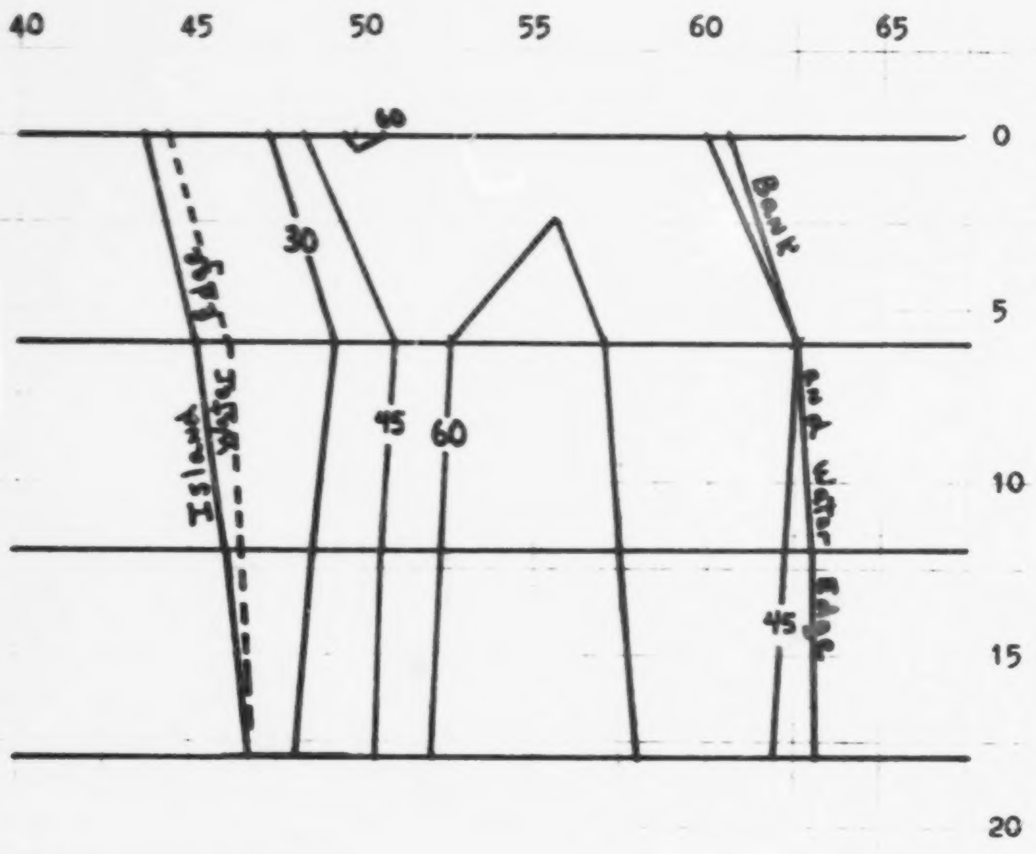


Velocity Contour Map

Birney Section, Left Channel Facing Downstream

Q = 15.7 m^3/sec = 555 cfs

Velocities in cm/sec, Units of length in meters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10
15
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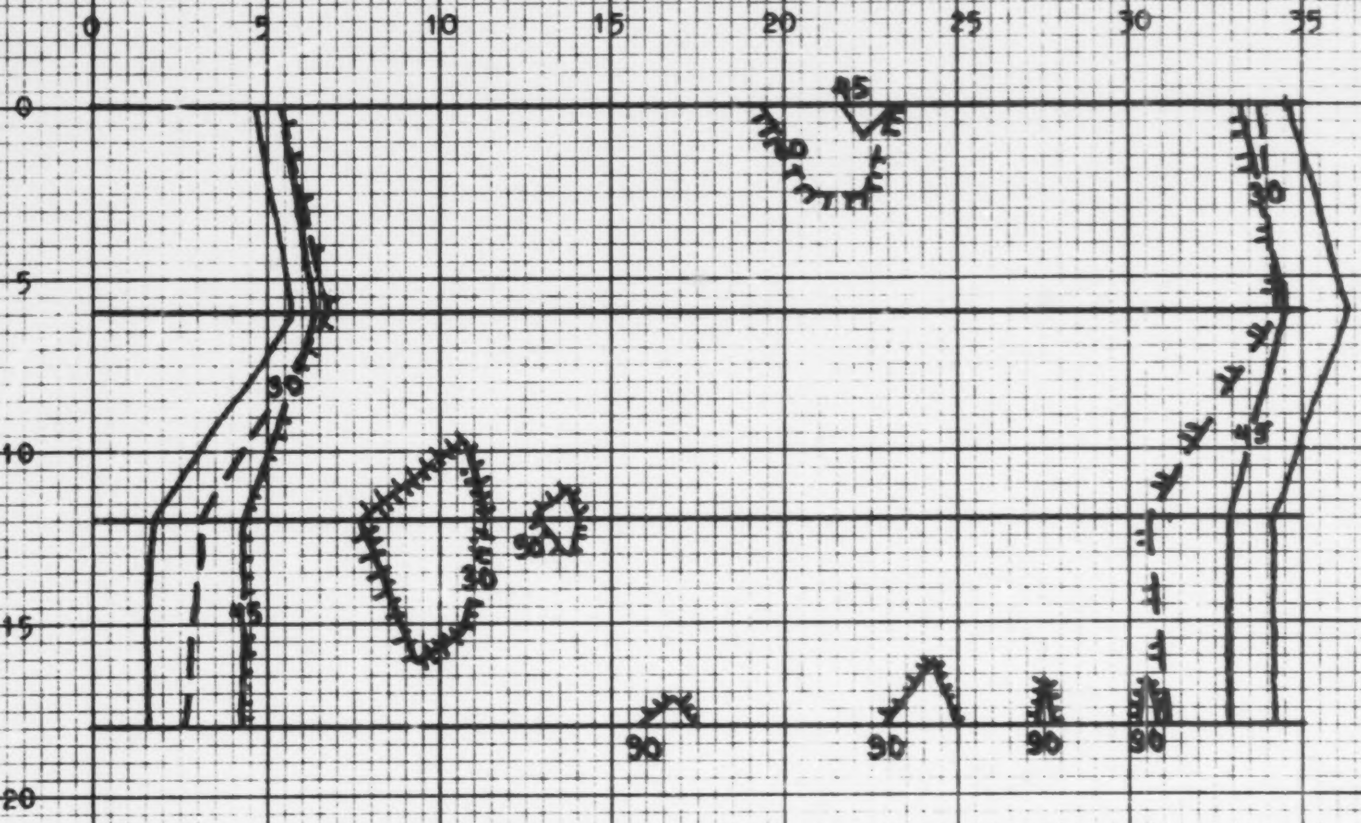
Island
Water Edge
30
45
60
60
Bank
End Water Edge
45

Depth Contour Map

Birney Section, Left Channel Facing Downstream

Q = 15.7 m^3/sec = 555 cfs

Depths in cm, units of length in meters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45
30
30
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45
30
30
45
90
90
90
90
90

Composite Map Showing Areas Meeting Depth and Velocity Criteria

Birney Section, Right Channel Facing Downstream

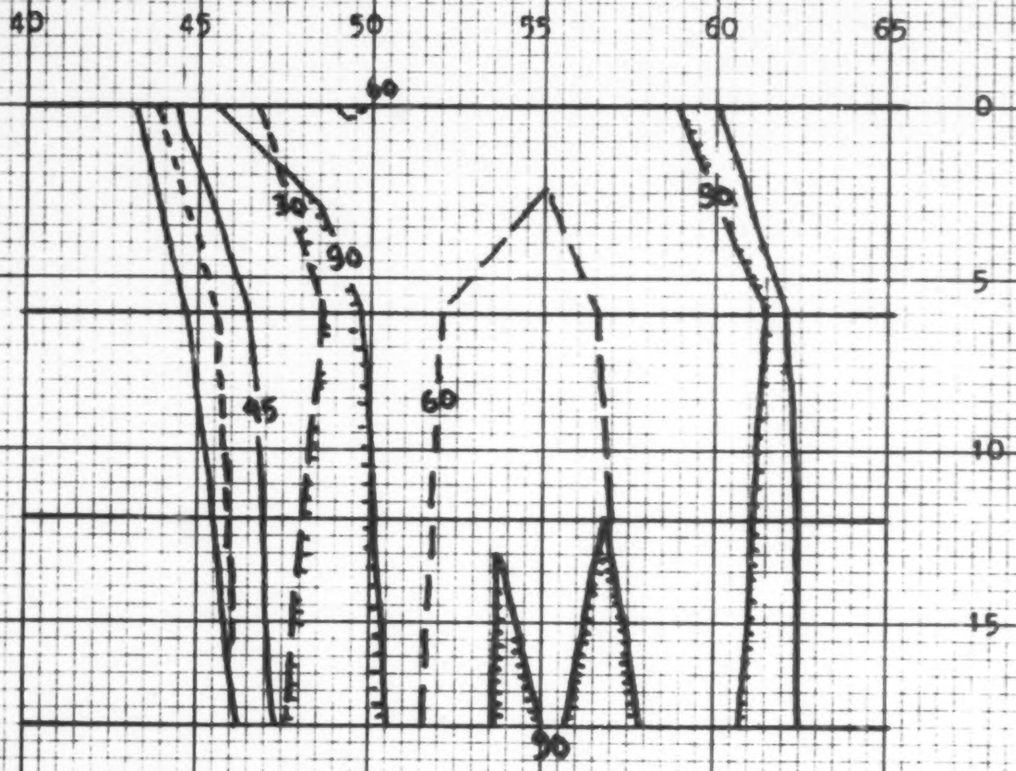
Q = 15.7 m^3/sec = 555 cfs

Total Water Surface Area = 551 m^2 Both Channels = 849 m^2

Total Area Meeting Criteria = 451 m^2 Both Channels = 497 m^2

Percent Total Meeting Criteria = 82% Both Channels = 59%

K+E 10 X 10 TO THE INCH 46 0703
7 X 10 INCHES
KEUFFEL & ESSER CO.



Composite Map Showing Areas Meeting Depth and Velocity Criteria

Birney Section, Left Channel Facing Downstream

$Q = 15.7\ m^3/sec = 555$ cfs

Total Water Surface Area, Left Channel Only = 298 m^2

Total Area Meeting Criteria, Left Channel Only = 45 m^2

Percent Total Meeting Criteria, Left Channel Only = 15%

K+E 10 X 10 TO THE INCH 46 0703
KEUFFEL & ESSER CO.

APPENDIX C

SUSPENDED AND BEDLOAD SEDIMENT DATA

TONGUE RIVER AND TRIBUTARIES

MARCH - MAY, 1975

Date	Q	$\overline{V}$	$\overline{D}$	Stage	Station	D_{35}	D_{50}	D_{65}	D_{90}	Bedload Transport Section*	Total
	m^3/sec	cm/sec	cm			mm	mm	mm	mm	(Tonnes per Day)	
4/16/75	13.6	--	--	F	A comp.	.315	.395	.485	.96	0.0972	15.3
4/16/75	13.6	--	--	F	B comp.	.325	.440	.59	1.25	0.0969	14.3
5/8/75	21.9	--	--	F	A comp.	.33	.51	.83	1.95	0.1079	16.9
5/8/75	21.9	--	--	F	B comp.	.37	.54	.76	3.70	0.1319	20.2
5/15/75	30.0	116	64	F	A R 1/3	.37	.49	.72	2.40	0.2621	----
5/15/75	"	130	92	F	A M 1/3	.26	.34	.46	1.20	0.1809	----
5/15/75	"	95	70	F	A L 1/3	.33	.44	.72	2.90	0.5092	----
5/15/75	"			F	A Comp.	.32	.42	.63	1.95	0.2298	35.8
5/15/75	"			F	B R 1/3	.19	.24	.36	1.65	0.1103	----
5/15/75	"			F	B M 1/3	.26	.43	.66	1.80	0.1901	----
5/15/75	"			F	B L 1/3	.39	.56	.88	2.65	1.0855	----
5/15/75	"			F	B Comp.	..35	.52	.74	1.90	0.2489	38.1

---

* Section total refers to tonnes per day per foot of width

BEDLOAD DATA   Stream- Tongue River   Location: Orcutt Ranch

Date	Temp. °C	Q m^3/sec	Stage	Station	Conc. mg/l	Sediment Discharge Metric TPD	Size Composition per cent by wt. <.062	>.062	d_{50} (mm)	Dissolved Solids mg/l
4/16/75	---	13.6	F	A L 1/3	66		----	----	----	----
4/16/75	---	13.6	F	A M 1/3	55		----	----	----	----
4/16/75	---	13.6	F	A R 1/3	56		----	----	----	----
4/16/75	---	13.6	F	Composite	59	85				
4/16/75	---	13.6	F	B L 1/3	95		----	----	----	----
4/16/75	---	13.6	F	B M 1/3	73		----	----	----	----
4/16/75	---	13.6	F	B R 1/3	60		----	----	----	----
4/16/75	---	13.6	F	Composite	76	110	----	----	----	----
5/8/75	14.0	21.9	F	A Comp.	338	785	78.8	21.2	<.062	600
5/8/75	14.0	21.9	F	B Comp.	316	734	79.9	20.1	<.062	600
5/15/75	17.0	30.0	F	A L 1/3	414		----	----	----	560
5/15/75	17.0	30.0	F	A M 1/3	425		----	----	----	560
5/15/75	17.0	30.0	F	A R 1/3	362		----	----	----	560
5/15/75	17.0	30.0	F	A Comp.	400	1278	82.5	17.4	<.062	560
5/15/75	18.5	30.0	F	B L 1/3	454		----	----	----	560
5/15/75	18.5	30.0	F	B M 1/3	406		----	----	----	560
5/15/75	18.5	30.0	F	B R 1/3	354		----	----	----	560
5/15/75	18.5	30.0	F	B Comp.	405	1293	78.1	21.9	<.062	560

SUSPENDED SEDIMENT DATA: Stream- Tongue River Location Orcutt Ranch

Date	Q	V	D	Stage	Station	D_{35}	D_{50}	D_{65}	D_{90}	Bedload Transport Section*	Total
	m^3/sec	cm/s	cm			mm	mm	mm	mm	(Tonnes per	day)
4/30	17.5			R	A Comp.	.56	.84	1.3	3.9	0.318	42.0
4/30	17.5			R	B Comp.	.26	.32	.42	1.05	0.053	8.1
5/13	33.9			R	A Comp.	.32	.42	.63	4.4	----[1]	----[1]
						.33	.44	.63	1.4	0.167	23.2

[1] A portion of this sample was spilled, so that quantitative analysis is impossible.

* Section total refers to tonnes per day per foot of width

BEDLOAD DATA: Stream- Tongue River Location- SH Ranch

Date	Temp. °C	Q m^3/sec	Stage	Station	Conc. mg/1	Sediment Discharge tonnes/day	Size Composition <.062 mm	>.062 mm	d_{50}	Dissolved Solids mg/1
4/30/75	---	17.5	R	A L 1/3	158	---	---	---	---	620
4/30/75	---	17.5	R	A M 1/3	147	---	---	---	---	620
4/30/75	---	17.5	R	A R 1/3	139	---	---	---	---	620
				A Comp.	148	253	---	---	---	620
4/30/75	---	17.5	R	B L 1/3	189	---	---	---	---	620
4/30/75	---	17.5	R	B M 1/3	130	---	---	---	---	620
4/30/75	---	17.5	R	B R 1/3	125	---	---	---	---	620
				B Comp.	148	253	---	---	---	620
5/13/75	16.0	33.9	R	A L 1/3	245	---	88.0	12.0	.062	770
5/13/75	16.0	33.9	R	A M 1/3	440	---	76.5	23.5	.062	770
5/13/75	16.0	33.9	R	A R 1/3	551	---	64.2	35.8	.062	770
				A Comp.	412	1486	71.0	29.0	.062	770
5/13/75	16.0	33.9	R	B L 1/3	341	---	92.8	7.2	.062	770
5/13/75	16.0	33.9	R	B M 1/3	405	---	82.1	17.9	.062	770
5/13/75	16.0	33.9	R	B R 1/3	476	---	68.2	31.8	.062	770
				B Comp.	407	1469	79.0	21.0	.062	770

SUSPENDED SEDIMENT DATA: Stream- Tongue River Location- SH Ranch

Date	Q m^3/sec	Stage	Station	D_{35} mm	D_{50} mm	D_{65} mm	D_{90} mm	Bedload Transport Section* (tonnes per day)	Bedload Transport Total (tonnes per day)
4/3/75	12.8	R	A Comp.	.61	.82	1.14	2.65	0.244	32
4/3/75		R	B Comp.	.75	1.03	1.52	4.18	0.171	24
4/15/75	15.8	R	A Comp.	.32	.385	.45	.82	0.020	2.6
4/15/75		R	B Comp.	.30	.385	.46	.88	0.015	2.1

*Section Total refers to tonnes per day per foot of width

BEDLOAD DATA: Stream- Tongue River Location- Viall Ranch

Date	Temp. °C	Q m^3/s	Stage	Station	Conc. mg/l	Sediment Discharge tonne/day	Size Composition <.062 mm	>.062 mm	Dissolved Solids mg/l
4/3/75	---	12.8	U	A R 1/3	111	---	---	---	----
4/3/75	---		U	A M 1/3	99	---	---	---	----
4/3/75	---		U	A L 1/3	83	---	---	---	----
				A Comp.	98	108			
4/3/75	---	12.8	U	B R 1/3	97	---	---	---	----
4/3/75	---		U	B M 1/3	63	---	---	---	----
4/3/75	---		U	B L 1/3	86	---	---	---	----
				B Comp.	82	91	---	---	----
4/15/75	---	15.8	R	A R 1/3	35	---	---	---	----
4/15/75	---		R	A M 1/3	34	---	---	---	----
4/15/75	---		R	A L 1/3	23	---	---	---	----
				A Comp.	31	51			
4/15/75	---	15.8	R	B R 1/3	48	---	---	---	----
4/15/75	---		R	B M 1/3	44	---	---	---	----
4/15/75	---		R	B L 1/3	36	---	---	---	----
				B Comp.	43	71			

SUSPENDED SEDIMENT DATA: Stream- Tongue River Location- Viall Ranch

Date	Temp. °C	Q m^3/s	Stage	Station	Conc. mg/l	Sediment Discharge tonne/day	Size Composition $<.062$ mm	$>.062$ mm	Dissolved Solids mg/l
3/24/75	3.0	10.1	F	Comp.	55	59			220
4/4/75	---	11.6	U	A R ½	34	18			600
4/4/75	---	11.6	U	A L ½	39	21			600
				A Comp.	36.5	39			
4/4/75	---	11.6	U	B R ½	50	27			600
4/4/75	---	11.6	U	B L ½	52	28			600
				B Comp.	51	55			600
4/15/75	---	11.3	F	A R ½	31	19			270
4/15/75	---	11.3	F	A L ½	32	19			270
				A Comp.	32	38			270
4/15/75	---	11.3	F	B R ½	24	14			270
4/15/75	---	11.3	F	B L ½	19	11			270
4/15/75	---	11.3	F	B Comp.	22	26			270
5/1/75	8.5	12.7	F	A R ½	16	11			560
5/1/75	8.5	12.7	F	A L ½	22	15			560
				A Comp.	19	26			
5/1/75	8.5	12.7	F	B R ½	15	10			560
5/1/75	8.5	12.7	F	B L ½	23	15			560
				B Comp.	19	26			560

SUSPENDED SEDIMENT DATA: Stream- Tongue River Location: Birney

Date	Q	Stage	Station	D_{35}	D_{50}	D_{65}	D_{90}	Bedload Transport	
	m^3/sec			mm	mm	mm	mm	Section* (tonnes per day)	Total
4/30	0.1	R	Comp.	.17	.205	.239	.465	.0128	.08

*Section Total refers to tonnes per day per foot of width

BEDLOAD DATA: Stream- Jack Creek Location- Tongue River Road

Date	Temp.	Q	Stage	Station	Conc.	Sediment Discharge	Size Composition			Dissolved Solids
		m^3/sec			mg/l	tonnes/day	<.062 mm	>.062 mm	d_{50}	mg/l
4/3/75	----	0.5	R	Comp.	28600	1400	45.0	55.0	.087	550
4/30/75	----	0.1	R	Comp.	2050	25	99.9	0.1	.062	810

SUSPENDED SEDIMENT DATA: Stream- Brown Creek Location- Tongue River Road

Date	Q	Stage	Station	D_{35}	D_{50}	D_{65}	D_{90}	Bedload Transport	
	m^3/sec			mm	mm	mm	mm	Section*	Total
								tonnes per day	
4/3/75	0.5	R	Comp.	.074	.084	.095	.114	0.0515	0.31

*Section total refers to tonnes per day per foot of width

BEDLOAD DATA: Stream- Brown Creek Location- Tongue River Road

Date	Temp. °C	Q m^3/sec	Stage	Station	Conc. mg/l	Sediment Discharge tonnes/day	Size Composition <.062 mm	>.062 mm	d_{50}	Dissolved Solids mg/l
4/3/75	---	0.5	R	Comp.	17170	840	92.2	7.8	<.062	550
4/30/75	----	0.5	R	Comp.	2400	118	98.1	1.9	.062	420
5/7/75	----	0.8	F	Comp.	7118	574	91.8	8.2	.062	550

SUSPENDED SEDIMENT DATA: Stream: Haddow Creek Location: Tongue River Road

Date	Q	Stage	Station	D_{35}	D_{50}	D_{65}	D_{90}	Bedload Transport Section*	Total
	m^3/sec			mm	mm	mm	mm	tonnes per day	
4/3/75	0.5	R	Comp.	.142	.173	.211	.375	0.130	1.2
5/7/75	0.76	F	Comp.	.157	.180	.205	.295	0.2147	3.4

*Section Total refers to tonnes per day per foot of width

BEDLOAD DATA: Stream- Haddow Creek Location- Tongue River Road

Date	Q m^3/sec	Stage	Station	D_{35} mm	D_{50} mm	D_{65} mm	D_{90} mm	Bedload Transport Section* tonnes per day	Bedload Transport Total tonnes per day
5/7/75	0.64	F	Comp.	.169	.182	.220	.400	0.0054	0.05

*Section total refers to tonnes per day per foot of width

BEDLOAD DATA: Stream- Foster Creek Location- Tongue River Road

Date	Temp. °C	Q M^3/s	Stage	Station	Conc. mg/1	Sediment Discharge tonne/day	Size Composition <.062 mm	Size Composition >.062 mm	Dissolved Solids mg/1
4/15/75		0.6	U	Comp.	43	2.7			----
5/7/75		0.7	F	Comp.	44	3.1			1400

SUSPENDED SEDIMENT DATA: Stream- Otter Creek Location- Ashland

Date	Temp. °C	Q m³/s	Stage	Station	Conc. mg/l	Sediment Discharge tonne/day	Size Composition <.062 mm	Size Composition >.062 mm	Dissolved Solids mg/l
4/4/75		0.3	U	Comp.	185	6			1800
4/15/75		0.35	R	Comp.	338	12			1010
5/1/75	8.3	0.4 e	F	Comp.	---*				2890
5/15/75	11.0	0.7 e	F	Comp.	26	2			2830

* Insufficient sediment in sample to make analysis.

SUSPENDED SEDIMENT DATA: Stream- Hanging Woman Creek Location: Birney

FISH DISTRIBUTION OF THE TONGUE RIVER AND TONGUE RIVER RESERVOIR AS RELATED TO MAJOR HABITAT AREAS, INSTREAM FLOW NEEDS AND PROPOSED COAL DEVELOPMENT

Section 2

by

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59301

FISH DISTRIBUTION OF THE TONGUE RIVER AND TONGUE RIVER RESERVOIR AS RELATED TO MAJOR HABITAT AREAS, INSTREAM FLOW NEEDS AND PROPOSED COAL DEVELOPMENT

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FISH DISTRIBUTION OF THE TONGUE RIVER AND TONGUE RIVER RESERVOIR AS RELATED TO MAJOR HABITAT AREAS, INSTREAM FLOW NEEDS AND PROPOSED COAL DEVELOPMENT

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FISH DISTRIBUTION OF THE TONGUE RIVER AND TONGUE RIVER RESERVOIR AS RELATED TO MAJOR HABITAT AREAS, INSTREAM FLOW NEEDS AND PROPOSED COAL DEVELOPMENT.

Al Elser
Montana Department of Fish and Game

BACKGROUND

The headwaters of the Tongue River rise in the Bighorn Mountains of Wyoming. The river generally flows northeast out of Wyoming, to its confluence with the Yellowstone River at Miles City. Flows in Montana are controlled by the Tongue River Dam. This 3,500 acre impoundment was constructed in 1938 by the Montana Water Resources Board as an irrigation storage reservoir. Above the reservoir, the river meanders through a broad open valley with a wide floodplain. Turbid water, slow velocity, muddy bottoms and warm temperatures characterize the stream. Downstream from the dam, the river flows for 10 miles through a narrow, restrictive canyon. As gradient increases, water temperatures cool and gravel bottoms are common. From the canyon to the river's mouth, the valley again broadens and physical characteristics change from those of the canyon into a slow, meandering stream.

The Tongue River is important to the people of southeastern Montana. It provides water for domestic use by man and livestock, irrigates crops and offers recreation.

As coal development threatens the Tongue River drainage, the river takes on a new importance. The Decker-Birney Resource Study of April, 1974, identified strippable coal reserves underlying 359,333 acres of the planning unit in the Tongue River drainage. Approximately 285,000 acres of this planning unit is composed of superior reserves - containing 15 billion tons of coal - which are economically feasible to mine. Other coal reserves exist outside the Decker-Birney unit, yet are associated with the Tongue River.

The Tongue River and Tongue River Reservoir will become increasingly important in light of proposed coal development. While most coal mined in Montana now leaves the state, coal conversion complexes (steam-fired generation, gasification and liquefaction plants) close to the coal source loom on the horizon. Such energy complexes require great amounts of water and the Tongue is considered an important source of industrial water.

In 1972, a new Tongue River dam site was identified by the Montana-Wyoming Aqueduct Study. The new reservoir would inundate about 12 more miles of Tongue River country and provide an additional 60,000 acre-feet of water. The magnitude of the proposed industrial use of the Tongue River makes it imperative that fish populations are inventoried and that adequate flow levels are insured to protect the fishery.

Fish population studies in Montana have received far less attention in warm water streams than in cold water streams. Two important aspects of warm water stream investigations are lacking: (1) few estimates of total fish population numbers have been made, and (2) fish collecting methods have not been devised and evaluated for warm-water environments (Larimore, 1961). Early interest in and high esteem placed on trout fishing has been the primary cause of differences. Another factor is the greater difficulties encountered in working warm-water streams with their more diversified habitats and larger, more varied fish populations.

OBJECTIVES

The objectives of this study are to inventory the fish populations of the Tongue River, its major tributaries and Tongue River Reservoir, to determine species composition, distribution and diversity indicies for various habitat areas occurring in the river system, to evaluate instream flow needs to determine flow levels adequate to protect the fishery, and to evaluate possible impacts of proposed coal development on the Tongue River Reservoir.

METHODS

Major habitat zones were delineated for the Tongue River through the use of aerial photos, U.S.G.S. quad maps, and on ground observations. Physical characteristics in each zone will be determined with the aid of the Water Surface Profile Program, developed by the Bureau of Reclamation. This program allows the users to predict and/or study various changes in stream characteristics at many different flows. The program model is calibrated to a specific stream section using one or two observed flows, the corresponding water surface elevations, and cross sectional data at various locations in the stream section (Dooley, 1975). These measurements are obtained through standard surveying methods.

Water temperatures were monitored utilizing a Taylor 30-day recording thermograph. The recording sheets were changed monthly. Daily maximum-minimum temperatures were tabulated. All water temperatures were recorded in Farenheit degrees.

Aquatic invertebrates were sampled by the Needham kick-screen method to evaluate species distribution. Samples were collected in September and November and were keyed by Robert Newell, Montana Department of Fish and Game.

Fish populations were sampled by several methods. Electrofishing gear with an output of 0-500 volts variable direct current was utilized to sample fish populations in the river and tributaries. The gear was fished either from a fiberglass boat as described by Vincent (1971) or from the banks of smaller streams. Baited hoop nets (3-foot hoops with 1-inch mesh webbing - and wire frame traps were fished for channel catfish. Trap nets with 4-foot by 6-foot frames (1/2-inch and 1/4-inch mesh) were utilized in the Tongue River Reservoir. A 100-foot, 1/4-inch mesh beach seine and a 4-inch bar mesh gill net was also utilized to sample fish populations. Numbered Floy filament tags were used to mark fish.

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Fish population statistics were calculated by computer as described by Vincent (1974). Species diversity indicies were calculated according to the formula described by Shannon and Weaver (1964).

RESULTS

PHYSICAL PARAMETERS

Collection areas were established on 11 reaches of the river downstream from the Tongue River Dam (Figure 1). Primary sampling sections (IB, IIB, IIIA, IVB, VB, VC) were established in relation to irrigation diversion structures to evaluate fish distribution (Table 1). Section VB was established as a major sampling section since the New Tongue River Dam was located in the section. Sections ranged in length from 8,200 feet to 13,332 feet, while gradients varied from 2.94 feet/mile near the mouth to 6.67 feet/mile in the canyon. There was a decrease in gradient progressing downstream (Figure 2). Secondary sections (IA, IIA, IIIB, IVA, VA) were established to delineate fish distribution in the river.

Water temperatures were recorded at station IA from March - December. Temperatures greater than 70° were recorded for 92 days and 47.8% of those days the temperature exceeded 80°. The maximum temperature recorded was 90° in mid-August. The mean monthly maximum and minimum temperatures are shown in Figure 3. Thermographs were installed at stations IIIA and VC.

Table 1. Description of major sampling sections, Tongue River.

Section	Location (miles) 1/	Upstream Barrier	Length (ft)	Gradient (ft/mile)
IB	14.1	T and Y Diversion	12,650	2.94
IIB	70.5	S-H Diversion	11,669	3.5
IIIA	90.6	Mobley's Diversion	13,332	4.00
IVB	156.7	Brewster's Diversion	11,669	3.45
VB	177.5	Tongue River Dam	8,870	6.67
VC	186.6	Tongue River Dam	8,200	6.45

1/ River miles above the mouth

FISH POPULATION-TONGUE RIVER

Species Distribution- Twenty-nine species of fish representing 10 families were collected during 1974 on the Tongue River. Common names of fishes used in this report correspond to those presented by the American Fisheries Society (1970). Of these species, three (burbot, shovelnose sturgeon and blue suckers) were taken only during the spring sampling near the mouth and are considered to be migrant species.

The nature of the qualitative distribution is shown in Table 2. Grouping by sections obscures the variation encountered but illustrates broad trends of fish distribution. Six species ranged the length of the

99<

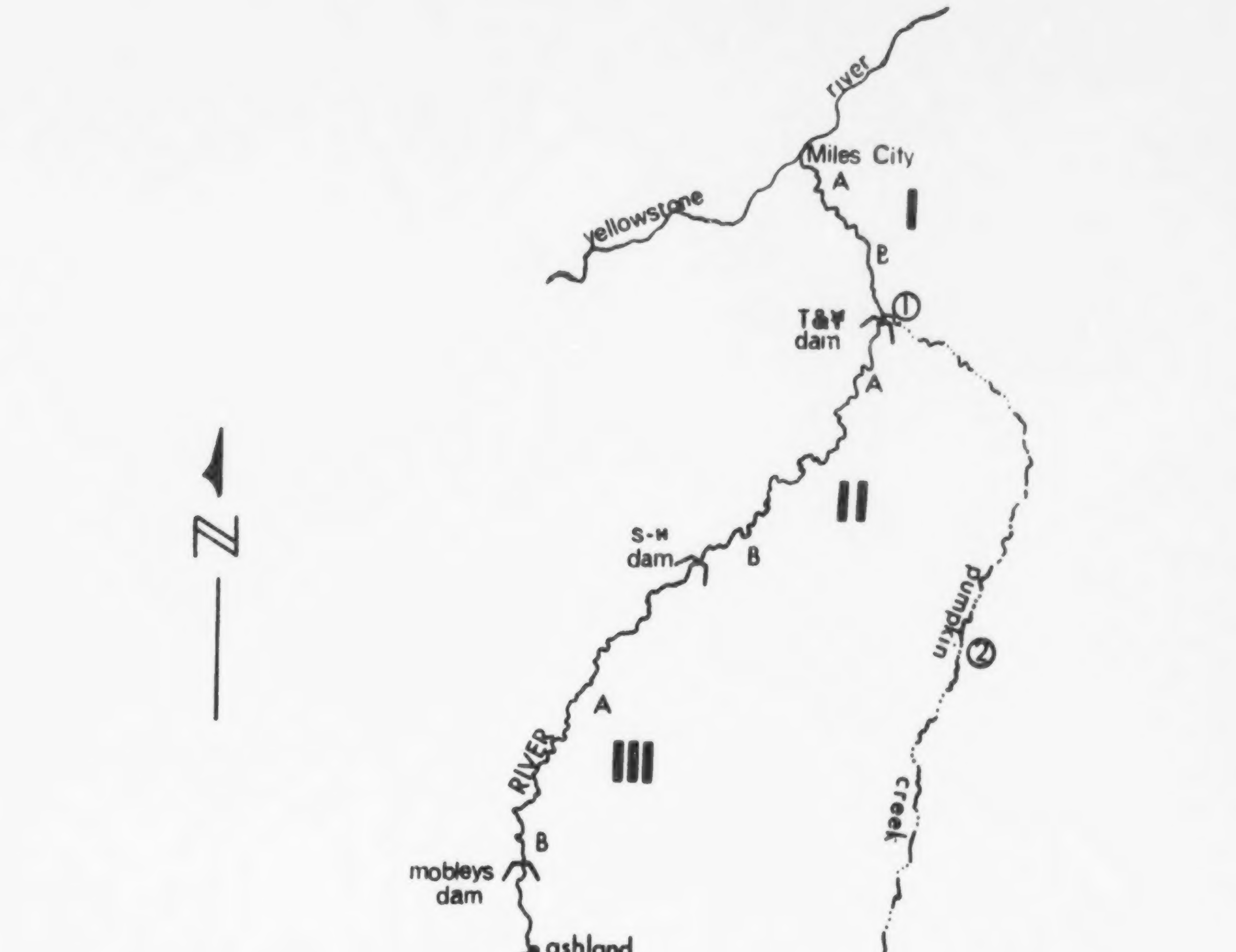
river
Miles City
yellowstone
A
I
B
①
T&Y dam
A
II
S-H dam
B
pumpkin
②
creek
N
A
III
RIVER
B
mobleys dam
ashland
①
A
TONGUE
IV
otter
creek
②
B
①
birney
brewsters dam
A
hanging woman
creek
②
B
V
③
C
④
decker
MONTANA
WYOMING
SCALE
0
10
20
30
miles

Figure 1. Map of the Tongue River, showing sampling sections and major tributaries.

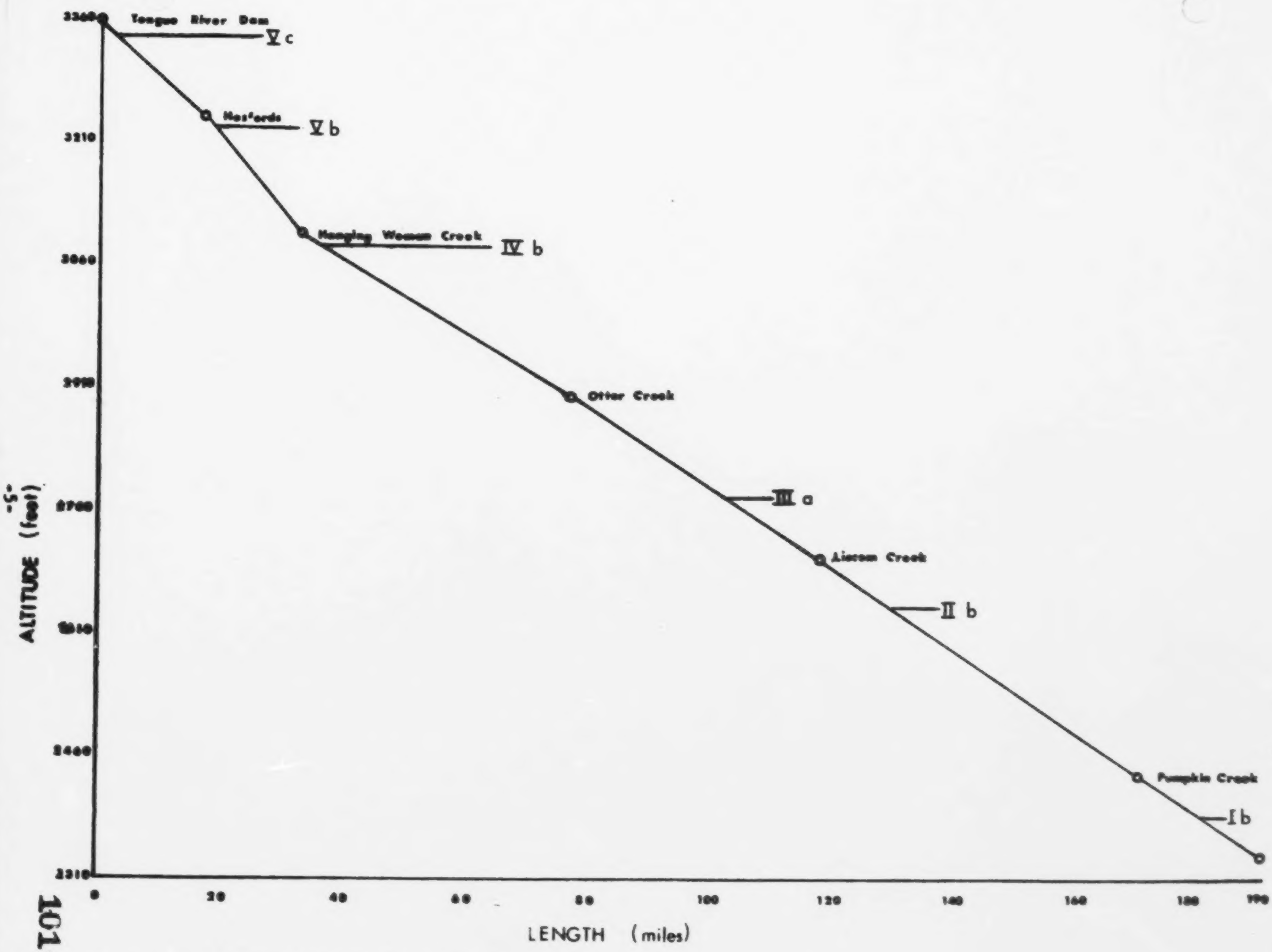

Figure 2. Longitudinal profile of the Tongue River from Tongue River Dam to its mouth.

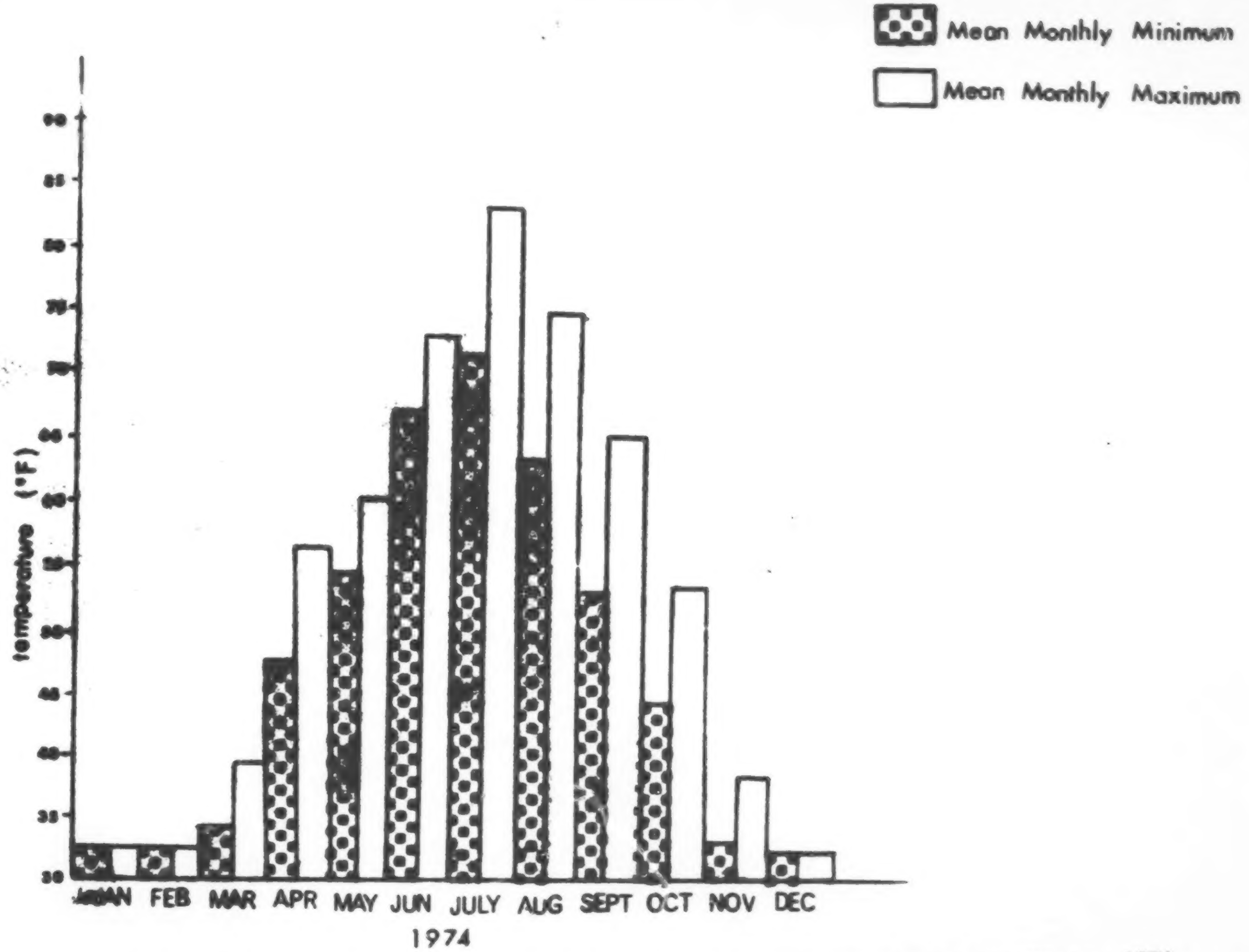

Figure 3. Mean monthly maximum and minimum temperatures for the Tongue River, 1974.

stream. Mountain whitefish and brown trout were confined to the upstream zone.

Longitudinal distribution of fish in the Tongue River is influenced by irrigation diversion structures. The T and Y diversion is the upstream limit for goldeye, walleye, burbot, shovelnose sturgeon, blue suckers and sturgeon chubs. Channel catfish did not occur above the S-H diversion. Flathead chubs are found upstream from the Mobley diversion, but in limited numbers when compared to downstream sections. Brewster's diversion is the upper limit for river carpsuckers and smallmouth bass.

Table 2. Distribution of fishes in the Tongue River by zones, in 1974.

	ZONE				
Species	V	IV	III	II	I
Carp	*	*	*	*	*
Stonecat	*	*	*	*	*
Shorthead redhorse	*	*	*	*	*
White sucker	*	*	*	*	*
Longnose sucker	*	*	*	*	*
Longnose dace	*	*	*	*	*
White crappie	*	*		*	*
Mountain sucker	*	*	*	*	
Rainbow trout	*	*	*		
Rock bass	*	*	*		
Black crappie	*	*			
Yellow perch	*	*			
Northern pike	*	*			
Whitefish	*				
Brown trout	*				
Green sunfish		*	*	*	
Smallmouth bass		*		*	*
Pumpkinseed		*			*
Black bullhead		*	*		
Flathead chub		*	*	*	*
Sauger		*	*	*	*
River carpsucker		*	*	*	*
Channel catfish				*	*
Goldeye					*
Burbot					*
Walleye					*
Shovelnose sturgeon					*
Blue sucker					*
Sturgeon chub					*
Total No. Species	15	20	14	14	19

Population Numbers and Species Composition- The fall electrofishing samples are summarized in Table 3. Estimates of total population numbers and biomass are not completed, therefore results are expressed as numbers and pounds of fish collected per mile of stream. Each sample is made up of six electrofishing trips. Numerically, flathead chubs were dominant in section

Table 3. Summary of electrofishing samples for the Tongue River, fall, 1974; expressed as number of fish per mi'e of stream (Total weight shown in parenthesis).

SPECIES	SECTION					
	IB	IIB	IIA	IVA	VB	VC
Goldeye	33 (17.5)					
Mt. Whitefish					1 (0.2)	
Rainbow trout				1 (0.9)	2 (4.0)	18 (20.3)
Brown trout						3 (2.6)
Northern pike				3 (18.8)		
Carp	58 (102.1)	65 (118.3)	4 (8.4)	27 (86.4)	33 (16.5)	79 (214.9)
Flathead chub	133 (6.6)	148 (13.3)	165 (11.6)	5 (0.3)		
Sturgeon chub	1 (T)					
Silvery minnow			2 (T)			
Fathead minnow		1 (T)				
Longnose dace	3 (T)	2 (T)	15 (0.3)	1 (T)	3 (0.1)	
River carpsucker	26 [illegible]	130 (49.6)	4 (2.7)	45 (39.2)		
Shorthead redhorse	88 (69.5)	216*(116.6)	73 (67.5)	283*(274.5)	14 (15.3)	296 (731.1)
Longnose sucker	8 (6.0)	47 (27.3)	21 (16.0)	62 (65.1)	76 (14.4)	770 (1239.7)
White sucker	8 [illegible]	8 (12.1)	22 (12.8)	125 (87.5)	311*(307.9)	151 (249.2)
Mountain sucker		1 (T)	9 (6.4)		1 (0.3)	8 (1.1)
Black bullhead			1 (0.1)	1 (0.6)		
Channel catfish	7 (10.3)	24 (70.3)				
Stonecat	9 (0.6)	40 (2.0)	41 (3.3)	65 (7.2)	82 (0.8)	34 (4.1)
Rock bass		1 (0.3)	5 (1.6)	30 (4.2)	11 (1.8)	
Green sunfish		1 (T)	1 (T)	7 (0.3)		
Pumpkinseed	1 (0.1)			7 (0.1)		
Smallmouth bass	1 (0.2)	2 (0.5)		88 (9.7)		
White crappie	2 (0.3)	2 (0.3)	2 (0.3)	2 (0.5)	2 (0.2)	1 (T)
Black crappie	1 (0.1)			1 (0.1)	1 (0.1)	
Yellow perch				3 (0.2)	4 (0.4)	10 (0.6)
Sauger	58 (56.3)	11 (9.9)	11 (9.9)	5 (4.6)		
Walleye	5 (5.3)					
Total	442 (313.7)	699 (420.3)	361 (106.0)	761 (600.2)	541 (362.0)	1370 (2463.6)
No. of Species	17	16	14	19	13	11

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IB (30.1% of the total number) and IIIA (45.7%), followed by shorthead redhorse (19.9 and 20.2%, respectively). Shorthead redhorse were dominant in sections IIB (30.9%), and IVB (37.2%). Carp dominated sections IB and IIB by weight, while shorthead redhorse predominated sections IIA, IVB, and VC. White suckers dominated section VB both numerically and by weight and longnose suckers were dominant in Section VC. Sucker distribution grades from predominately longnose in section VC, to white sucker dominance in section VB, with shorthead redhorse dominance in the remaining reaches (Figure 4).

Game fish concentrations were heaviest in section IVB and made up 12.7% of the total number, with smallmouth bass the dominant game fish. Smallmouths ranged in length from 2.1 to 13.5 inches and the preponderance of young-of-the-year fish indicates that they are successfully reproducing. Smallmouth bass were also found downstream from the S-H diversion, but the greatest concentration was near Birney.

Northern pike were also captured in section IVB. The inclusion of small northerns (9.3 inches in length) suggests that these fish are also reproducing in the river. The lower reaches of Hanging Woman Creek would provide excellent northern pike spawning habitat and probably acts as a nursery area for the Tongue River population of northerns.

The Tongue River supports the only rock bass population in Montana. Greatest numbers of rock bass were found in sections IVB and VB. All size classes were represented in the samples.

The greatest number of channel catfish was found in section IIB, with the largest fish weighing 7.25 pounds. Sauger were most abundant near the mouth, in section IB, and made up 13.1% of the total numbers captured. The largest sauger caught weighed 2.50 pounds.

Species Diversity- Species diversity indicies have been used by biologists to provide insight into the structure of natural communities and as possible indicators of qualitative aspects of their surrounding environments. A low diversity index ($\bar{d}$) indicates a largely monotypic community dominated by a few abundant organisms, while a high diversity index suggest a heterogeneous community in which abundance is distributed more evenly among a number of species (Robert Newell, personal communication). Redundancy (R) was also used as an index of the repetition of information within a community, expressing the dominamce of one or more species and is inversely proportional to the wealth of the species (Wilhm and Dorris, 1968).

While species diversity indicies have been used extensively with benthic macroinvertebrates to evaluate degradational environmental conditions, they have recently been applied to fish populations (Sheldon, 1968; Jackson and Harp, 1973; and Harima and Mundy, 1974). Indicies of species diversity ($\bar{d}$) and redundancies (R) were calculated for the 6 primary sampling sections on the Tongue River. The diversity indicies increased with progression downstream (Figure 5), indicating an increase of rarer species in the lower reaches. One exception was section IVB, which did not fit the curve. This section had the greatest number

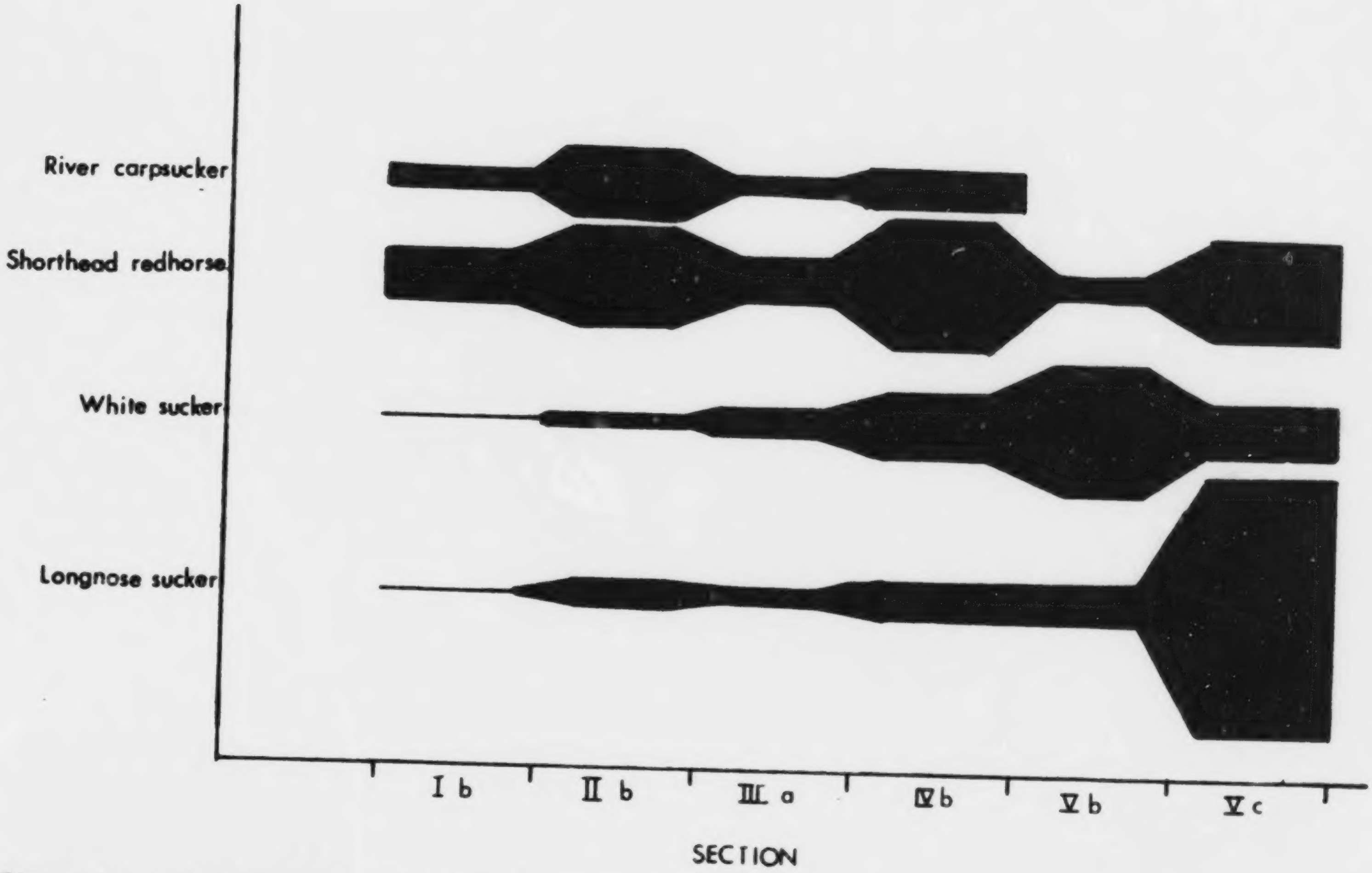

Figure 4. Longitudinal distribution of suckers in Tongue River. The width of the line indicates abundance of a species, w th the widest place where the greatest numbers were present and can be used as a comparison

of species, many represented by few individuals. However, as Jackson and Harp (1973) showed, longitudinal distribution in a stream is not necessarily a continuous change since specific conditions and populations may reappear at intervals throughout the stream system. Redundancy substantiates the d concept since R increases with dominance by one or more species (Figure 5). Fish populations in the upstream sections were dominated by one or two species represented by a large number of individuals. And the populations in the lower reaches lack a strongly dominant species.

Measures of species diversity add another handle to the quantitative and qualitative description of a fishery. By collecting baseline data a change in the fish population can be observed by comparing diversity and redundancy. It is a generally accepted concept that a large-scale environmental stress exerted upon a diverse biological community results in a reduction of species diversity (Cairns, 1969).

Tagging - A total of 1,060 fish were tagged in the Tongue River during 1974 to evaluate movements and relative angler harvest (Table 4). Migrant shovelnose sturgeon, sauger, walleye, channel catfish and other non-sport fish were tagged in the spring in an attempt to determine home ranges of these fish in the Yellowstone River. Of 421 shovelnose sturgeon tagged, only 3 (0.71%) fish were returned, all from the Yellowstone. Sauger tag returns were also higher in the Yellowstone than in the Tongue (2.33% as compared to 0.33%, respectively). A total angler return rate of 1.51% suggests a fishery resource that is not being utilized by anglers.

Age and Growth - Scales were collected from all species taken in the primary sampling sections as a comparison of age and growth. Scales are currently being prepared for analysis and will be worked during the next quarter.

Migrant Fish Populations- Sampling during the spring of 1974 in the lower reaches of the Tongue River (downstream from the T and Y Diversion) revealed a large number of fish moving into the river from the Yellowstone. Sauger, shovelnose sturgeon and blue suckers moved into the river in sizable numbers. Gonadal development suggested spawning runs were being made by these fish. Sauger concentrations became obvious from fishermen use during mid-April and were present in the river until spring run-off precluded sampling efforts.

The run of shovelnose sturgeon was monitored during the period April 4 to July 8, with 427 fish captured (Peterman and Haddix, 1975). A total of 421 sturgeon were tagged and released. Two methods were used to tag sturgeon in 1974. Serially numbered Floy (FD-67) anchor tags were placed immediately posterior to the dorsal fin and number 3 monel wing band tags were placed over the anterior fin rays of the pectoral fin (Helms, 1974).

Shovelnose sturgeon were sampled again in the lower Tongue in 1975. Through June 13, 485 fish were captured, tagged and released. Sampling is continuing at the writing of this report. The first sturgeon was captured in 1975 on May 9 as compared to April 4 in 1974. However,

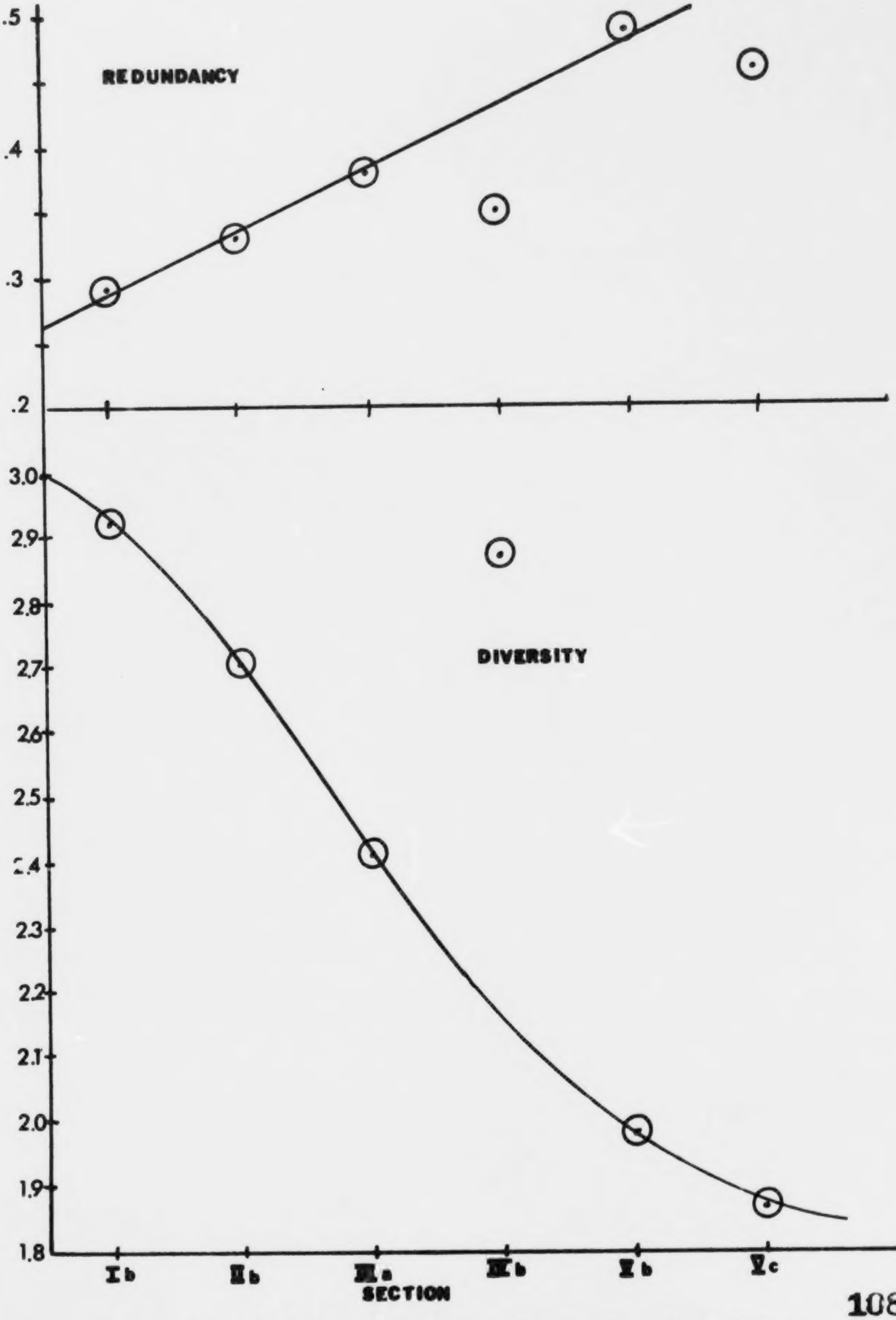

Figure 5. Species redundancy and species diversity curves for number of individuals for the Tongue River.

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Table 4, Summary of fish tagging and angler returns, Tongue River, 1974. (Percent returns shown in parenthesis).

Species	Number Tagged	Tongue River	Yellowstone River	Total
Shovelnose sturgeon	421	-	3 (0.71)	3 (0.71)
Sauger	301	1 (0.33)	7 (2.33)	8 (2.66)
Channel catfish	194	1 (0.52)	1 (0.52)	2 (1.03)
Smallmouth bass	34	1 (2.94)	-	1 (2.94)
Rock bass	33	-	-	-
Rainbow trout	28	1 (3.57)	-	1 (3.57)
Walleye	16	1 (6.25)	-	1 (6.75)
Burbot	11	-	-	-
Blue sucker	11	-	-	-
Northern pike	5	-	-	-
White crappie	3	-	-	-
Bigmouth buffalo	2	-	-	-
Drum	1	-	-	-
Total	1060	5 (0.47)	11 (1.04)	16 (1.51)

large concentrations of fish were not found in 1974 until around May 9 (Peterman and Haddix, 1975). Cooler water temperatures in 1975 may have caused the later arrival of fish. Numbered Floy (FD-67) anchor tags were used in 1975, but were placed through the pectoral girdle as described by Helms (1975).

Average lengths and weights of fish captured in 1975 were 29.4 inches (fork length) and 5.26 pounds, respectively (Table 5), and are comparable to fish taken in 1974, 30.2 inches (fork length) and 5.35 pounds, respectively. The largest fish taken in 1974 weighed 15.5 pounds as compared to a maximum of 13.25 pounds in 1975. The weight-frequency distribution is also comparable between years. In 1974, 26.0% of the fish weighed six pounds or more, 11.0% weighed 8 pounds or more and 5.0% weighed 10 pounds or more (Peterman and Haddix, 1975), as compared to 26.9% greater than 6 pounds, 10.9% greater than 8 pounds and 2.5% greater than 10 pounds in 1975. The Tongue River run appears to be composed of larger sized fish than reported elsewhere. In the lower Missouri River, the average weight was about one pound, with four pound fish considered rare (Schmulbach, 1974), while the average size reported by Helms (1974) from the Mississippi River was between 2 and 3 pounds. Limited sampling in the Yellowstone near Intake also revealed smaller fish with a average weight of 2.19 pounds (Peterman and Haddix, 1975). The larger size of fish in the Tongue may result from sampling a spawning population. Still, the numberof fish greater than maximums reported in other areas is significant.

Tag returns of 1974 fish taken during routine sampling in 1975 totaled 7.4% (31 of 420) through June 13. Of 240 fish tagged with monel tags, 19 (7.9%) have been returned, compared to 6.6% (12 of 180) Floy anchor tag returns. Through June 13, the tag return rate of 485 sturgeon tagged in 1975 was running 5.4%. Angler returns have been slight, averaging less than 0.5%, suggesting low harvest rate.

Monel tag returns showed that the tag had become completely encased with skin tissue and appeared simply as a raised area on the fin. Calculating growth rate on tag returned fish revealed that all fish tagged with monel tags had lost considerable weight, while Floy tagged fish showed weight gain. Eighteen fish returned with monels lost an average of 0.80 pound per fish (range of 0.31 - 3.00 pounds), while 11 fish returned with Floy tags showed a weight gain of 0.32 pound per fish (range of 0.0 - 0.85 pounds). Apparently monel tags caused a physiological change significant enough to result in a weight loss.

Other fish taken coincidentally with sturgeon sampling were tagged and released (Table 5). Tag returns were collected from sauger which had been tagged in 1974. All returns came from approximately the same place where they were tagged. Several paddlefish were observed during shocking operations on the lower Tongue. While none were collected due to their large size, their presence in the Tongue River shows the importance of the river.

Table 5. Summary of fish sampling in the lower Tongue River, April 23-June 13, 1975.

Species	Number	Average Length 1/	Average Weight	Number Tagged
Shovelnose sturgeon	485	29.6	5.26	485
Sauger	104	15.2	1.02	89
Channel catfish	37	20.7	4.53	37
Blue suckers	13	27.1	6.56	13
Bigmouth buffalo	12	21.5	6.23	12
Walleye	2	18.5	1.97	2
Northern pike	1	28.2	6.50	1
Smallmouth bass	1	14.8	1.84	1
Ling	1	13.3	0.58	1
Drum	1	19.8	4.28	1
Total	658			643

1/ Fork length

Passage and spawning flow requirements are an important consideration in determining instream flow needs for fish. Apparently a large number of Yellowstone River fish utilize the lower Tongue River as a spawning and nursery area. It will be important to monitor the use of the Tongue by spawning fish to evaluate passage flow needs and to attempt to locate spawning areas to determine spawning needs. Effort will be expended during the next quarter to locate spawning areas and evaluate passage flow requirements.

Fish Populations of Tributaries- Fish populations were sampled in the major tributaries of the Tongue River to evaluate species distribution and species composition. The major tributaries and river mile at its confluence with the Tongue are: Pumpkin Creek, 20.0; Otter Creek, 112.7; and Hanging Woman Creek, 156.7. Two sampling sites were establishedon Pumpkin and Otter Creeks and four on Hanging Woman Creek.

The distribution of fish for the tributaries is shown in Table 6 and 7. The stations nearest the mouth in each tributary showed the greatest number

Table 6, Distribution of fish in Pumkin Creek and Otter Creek, 1974.

Pumpkin Creek			Otter Creek Stations		
Species	1	2	Species	1	2
Carp	*	*	White sucker	*	*
Channel catfish	*	*	Pumkinseed	*	*
Goldeye	*		Carp	*	
Flathead chub	*		River carp sucker	*	
Longnose dace	*		Shorthead redhorse	*	
Shorthead redhorse	*		Black bullhead	*	
White sucker	*		Yellow bullhead	*	
Mountain sucker	*		Green sunfish	*	
Stonecat	*		Smallmouth bass	*	
White crappie	*		White crappie	*	
Sauger	*		Yellow perch	*	
Unknown 1	*		Unknown 4		*
Unknown 2		*			
Unknown 3		*			
Total Number species	12	4		11	3

Table 7. Distribution of fish in Hanging Woman Creek, 1974.

Species	1	2	3	4
Flathead minnow	*	*	*	*
White sucker	*	*	*	*
Green sunfish	*	*	*	
Carp	*	*		*
Lake chub	*		*	*
Hybopsis sp		*		*
Longnose dace		*		*
Black bullhead	*	*		
Yellow bullhead	*	*		
White crappie	*			
Total Number of Species	8	8	4	6

of species. Pumpkin Creek had the most species. Pumpkin Creek had the most species with 12. Most species were similar to those found in the main-stem. Exceptions were greatest in Hanging Woman with four species not found in the Tongue River.

Young northern pike captured near the mouth of Hanging Woman Creek (Section IVB) suggested that northerns may use the creek as a nursery area. Fish use of Hanging Woman Creek was monitored during the spring of 1975 with the use of a temporary fish trap. The leads of the trap were constructed from 1-inch mesh chicken wire and a frame trap net served as the body of the trap. A total of 134 upstream migrants were taken in the trap. White suckers were predominant (77.6%) followed by carp (9.7%). Other fish taken in the order of abundance were: northern pike (5.2%), river carpsuckers (4.5%), shorthead redhorse (2.2%) and green sunfish (0.8%).

Mature northerns of both sexes indicates that the tributary is important to maintaining the integrity of the Tongue River system. The northern pike averaged 23.4 inches in length (range 19.7 - 30.6) and 3.54 pounds in weight (range 2.25 - 7.37). The close proximity of the trap to Birney resulted in some piracy of trapped fish. Since northerns and other fish apparently utilize Hanging Woman Creek, it is important to establish instream flow standards on the Tongue River and its tributaries.

FISH POPULATIONS - TONGUE RIVER RESERVOIR

The Tongue River Reservoir and a portion of the drainage upstream were chemically treated in 1957 to remove undesirable fish species. Following rehabilitation, the reservoir was stocked with rainbow trout in an attempt to duplicate fishing which commonly follows the initial impounding of reservoirs. A total of 2,406,824 fingerling rainbow trout were planted during the years 1958-1960. Gill net sampling in November, 1959 produced 80 rainbow trout per net night, while sampling in January, 1960 took only 7 rainbow per net night. Stocking with trout was stopped because the undesirable fish had again built up to high population levels. However, correspondence in 1962 suggests that the reservoir was still producing some good catches of rainbow trout, with fish ranging from 1½ to 6 pounds being harvested by anglers.

Stocking recommendations for a warm water fishery in the reservoir were implemented in 1963 and are summarised in Table 8. Northern pike fry and fingerling were stocked in 1963-1966 to develop a self-sustaining population. No northerns were planted in 1967 and 1968, as a check on natural reproduction, but were again planted in 1969-1974. In 1972, 1973 and 1974, fingerlings were planted, rather than fry, to determine differential survival rates. Channel catfish were introduced in 1963 and 1964, and largemouth bass were planted in 1964 and again in 1972 and 1973. Attempts were made to establish a walleye pike fishery during the years 1965-1969. Since the first plant of walleyes would have matured in 1970, this plant was dropped as a check on spawning success.

Frame trap nets were fished during April, May and June to establish indicies of the spawning strength of sport fish populations. Seven traps were fished a total of 153 nights. The reservoir was divided into three zones (Figure 6) and the traps were located in areas that appeared to be good spawning habitat.

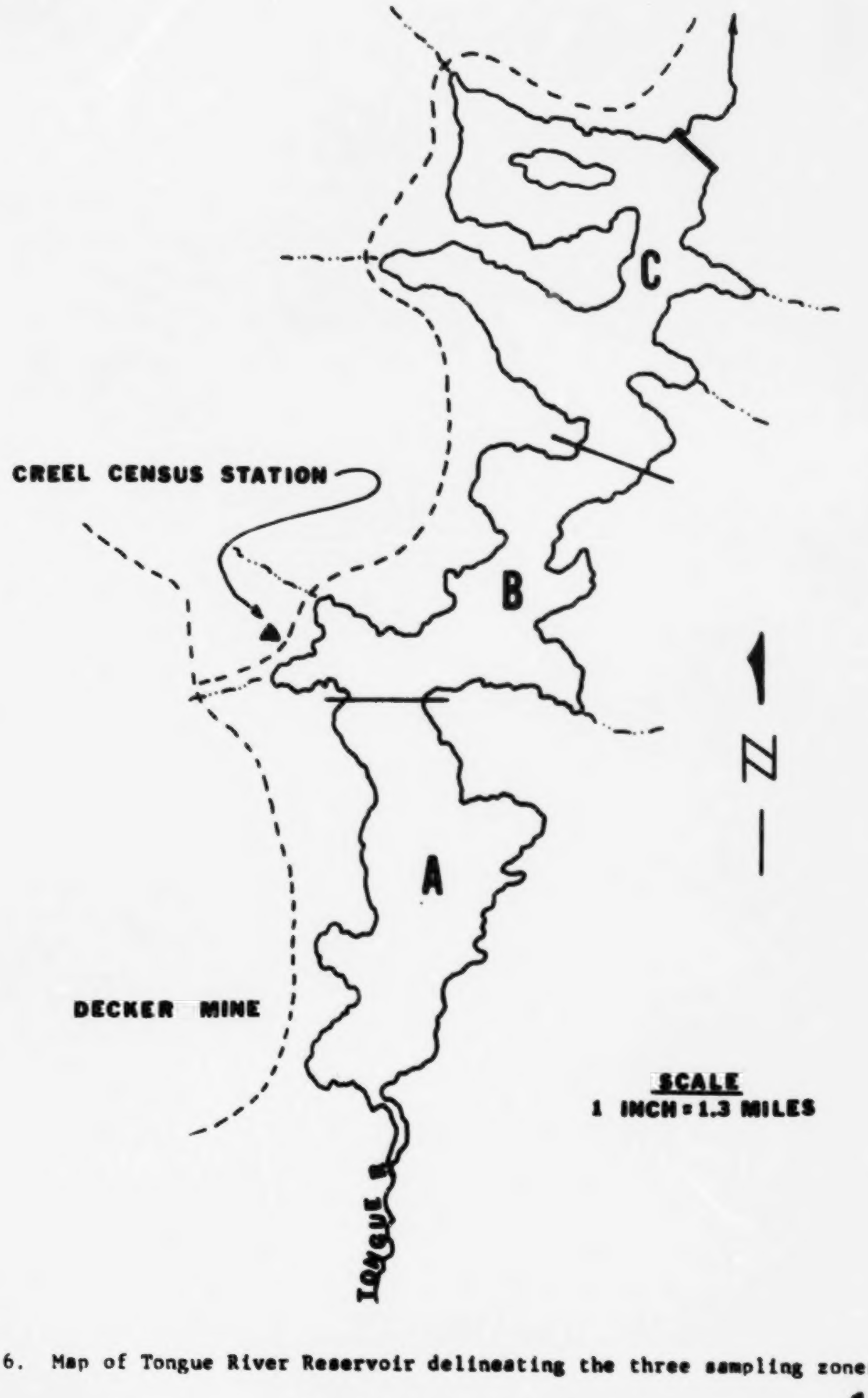
C
CREEL CENSUS STATION
B
N
A
DECKER MINE
SCALE
1 INCH = 1.3 MILES
TONGUE R.

Figure 6. Map of Tongue River Reservoir delineating the three sampling zones.

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Table 8. Summary of warm water fish plants in the Tongue River Reservoir, 1963-1973.

Year	Species	Size	Number
1963	Northern pike	fry	210,000
	Northern pike	fingerling	35,200
	Channel catfish	3"	20,608
1964	Northern pike	fry	100,000
	Channel catfish	2"	99,180
	Largemouth bass	1"	150,000
1965	Northern pike	fry	339,300
	Walleye pike	fry	750,000
1966	Northern pike	fry	210,500
	Walleye pike	fry	100,000
1967	Walleye pike	fry	197,750
1968	Walleye pike	fry	601,214
1969	Northern pike	fry	650,000
	Northern pike	fingerling	513,200
	Walleye pike	fry	92,480
1970	Northern pike	fry	1,125,000
1971	Northern pike	fry	360,000
1972	Northern pike	fingerling	14,058
	Largemouth bass	2"	199,290
1973	Northern pike	fingerling	13,184
	Largemouth bass	2"	27,540
1974	Northern pike	fingerling	3,330

Trap net catches for 1975 are compared with catches for 1972, 1973, and 1974 in Table 9.

A total of 6,035 fish were captured in 1975 through June 7. Traps are still being fished for black and white crappie and smallmouth bass. White crappie were the predominant fish taken, followed by yellow perch. Carp, yellow perch and white crappie dominated the catch in 1972, 1973 and 1974, respectively (Elser, 1973, 1974).

Game fish made up 4.8 percent of the total catch in 1975 as compared to 8.7 percent in 1974. Catch statistics of northern pike and walleye are shown in Table 10. Northern pike were taken almost exclusively in zone A with

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these traps accounting for over 94% of the northern catch (Table 11). This area is obviously best suited for northern pike reproduction with shallow bays. The increase in northern pike numbers in 1974 and 1975 is assumed due to increased survival of fingerling plants.

The walleye catch was distributed about equally between zones A and B, contributing 42.0 and 39.8 percent, respectively. The remaining 18.2 percent were taken in zone C. Black and white crappie showed distributional patterns, with 56.2% of the blacks being caught in zone C. White crappie were most abundant in zone B (71.0%), followed by zone A (23.7%). Only 5.3% of the white crappie were caught in zone C. This distribution is probably the result of differential water quality between the upper and lower ends of the reservoir.

Table 9. Comparison of trap net catches - Tongue River Reservoir 1972-1975, expressed as numbers per net night.

	1972		1973		1974		1975 1/	
Species	No.	%	No.	%	No.	%	No.	%
Northern pike	0.34	1.78	0.25	1.79	0.95	5.79	1.12	2.83
Carp	7.05	37.10	3.39	24.40	1.46	8.90	4.00	10.14
Goldfish	0.01	0.05	0.02	0.14	0.10	0.61	0.23	0.58
Golden shiner	0.09	0.47	0.11	0.79	0.04	0.24	1.03	2.61
Shorthead redhorse	0.13	0.68	0.21	1.51	0.29	1.77	0.18	0.46
White sucker	0.19	1.00	0.49	3.52	0.30	1.83	0.33	0.84
Longnose sucker	-		0.03	0.21	0.03	0.18	-	
Black bullhead	1.51	7.94	0.43	3.09	0.55	3.35	0.34	.86
Yellow bullhead	-		-	-	0.26	1.59	0.36	0.91
Stone cat	-		0.01	0.07	0.01	0.06	0.03	0.08
Largemouth bass	0.01	0.05	-		0.02	0.12	-	
Smallmouth bass	0.01	0.05	0.01	0.07	0.03	0.18	0.07	0.18
Rock bass	-		0.01	0.07	0.01	0.06	0.05	0.13
Green sunfish	-		0.02	0.14	0.02	0.12	0.05	0.13
Black crappie	1.24	6.52	1.30	9.35	2.99	18.24	4.44	11.26
White crappie	1.99	10.47	3.50	25.19	7.96	48.55	21.71	55.05
Sauger	-		0.02	0.14	0.09	0.55	0.12	0.30
Walleye	0.38	2.00	0.12	0.86	0.33	2.01	0.58	1.47
Yellow perch	6.05	31.84	3.96	28.56	0.96	5.85	4.80	12.17
Total	19.00		13.89		16.4		39.44	
No. Trap nights	85		121		168		153	

1/ Through June 7

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Table 10. The average lengths and weights of northern pike and walleye caught in trap nets in the Tongue River Reservoir, 1972-1975.

	Northern pike				Walleye			
Year	No.	Average Length (in)	Range (in)	Average Wt. (lbs)	No.	Average Length (in)	Range (in)	Average Wt. (lbs)
1972	29	29.4	23.5-42.5	8.25	32	19.5	14.1-22.4	2.94
1973	48	28.8	25.5-46.8	8.26	24	21.3	14.3-25.4	3.62
1974	140	28.3	15.5-45.5	6.47	44	20.1	12.0-31.1	3.32
1975	131	31.8	11.1-51.2	6.79	87	18.5	10.6-32.0	2.68

Numbered Floy (FD-67) anchor tags were placed in a total of 424 sport fish to evaluate growth rates, movement and relative fishermen harvest (Table 12). A total of 158 (37.3%) tagged fish have been taken in subsequent years during the spring trapping season (Table 13). Black crappie returns were highest, with 23 returns out of 38 tagged fish (60.5%). All black crappie which were tagged were large (up to 3.0 pounds), and returned to the same trap area where they were tagged. Northern pike returns averaged 58.8 percent (130 returns out of 221 tagged fish). In 1975, 171 northern pike were captured, of which 89 (52.0%) were tag returns, suggesting a high percentage of the northern population is tagged. Black and white crappie are marked by removing the left pectoral fin. An estimate of population strength will be made using the Schnabel estimator.

Angler returns for northern pike are averaging 9.3 percent with a 17.1 percent return rate two years after tagging and 6.4 percent return rate one year following tagging. Walleyes tagged in 1974 have shown a 5.9 percent rate of return while smallmouth bass tagged the same year were returned at a 33.3 percent rate. In 1975, anglers returned three tags within the first two months following tagging. The small rate of tag return suggests harvests well within tolerable limits of the fish populations.

Growth rates were calculated for tagged northern pike, black crappie and white crappie. Eleven northerns returned two years following tagging gained an average 2.2 inches and 2.20 pounds, while 33 fish recaptured the year following tagging increased in length by 1.9 inches and in weight by 1.54 pounds. One year after tagging, seven black crappie grew an average of 1.1 inches and 0.32 pounds, while one white crappie return gained 0.6 inches and 0.42 pounds in a year.

A creel census was initiated, designed to obtain fisherman use on the reservoir and angler harvest. A creel census station located on the main access road to the reservoir is operated one week day and one weekend day each week. Anglers are interviewed to determine residence, length of fishing trip and number of fish caught. The data is recorded on a standardized form and will be analyzed with the aid of a computer program.

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Table 11. Summary of trap net catches by zone in the Tongue River Reservoir, 1975

Species	April			May			June			Total			Total
	A	B	C	A	B	C	A	B	C	A	B	C	
Northern pike	67	1	1	89	6	2	5			161	7	3	171
Carp	195	23	27	264	53	34	9	7		468	83	61	612
Goldfish	21		1	11	1		1			33	1	1	35
Golden shiner	17	1	1	15	60	8	4	51	1	36	112	10	158
Shorthead redhorse	2			9	5	5	3	2	1	14	7	6	27
White sucker	5		2	1	5	8	2	2	26	8	7	36	51
Longnose sucker	0												
Black bullhead	11	1		13	20	4	1	1	1	25	22	5	52
Yellow bullhead	2			2	33	10	1	5	2	5	38	12	55
Channel catfish	0												
Stonecat	0				3			2			5		5
Largemouth bass													
Smallmouth bass					9	1			1		9	2	11
Rock bass				1	7					1	7		8
Green sunfish	2			1	2	2	31	46	283	3	2	2	7
Black crappie	34		2	62	125	97	493	1639	88	127	171	382	680
White crappie	83	2		211	717	89				787	2358	177	3322
Sauger	2	3		11		2	3	1		13	3	2	18
Walleye	26	31	9	8	3	7	3	12		37	35	16	88
Yellow perch	75	11		9	83	542				87	106	542	735
Total	542	73	43	707	1132	811	556	1768	403	1805	2973	1257	6035
Fish/night	27.1	14.6	14.3	17.2	34.3	35.3	55.6	160.7	57.6	25.8	60.7	38.1	39.44
Trap nights	20	5	3	41	33	23	10	11	7	71	49	33	153

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Table 12. Summary of tagged fish in Tongue River Reservoir, 1973-1975

Species	1973	1974	1975
Northern pike	41	110	70
Walleye	10	34	76
Sauger	1	9	8
Largemouth bass		2	1
Smallmouth bass	2	3	9
Black crappie		19	19
White crappie		6	4
Total	54	183	187

Table 13. Summary of tagged fish returns in trap nets, Tongue River Reservoir, 1972-1975.

	Northern pike		Walleye		Black Crappie		White Crappie	
Year	Tagged	% Ret.	Tagged	% Ret.	Tagged	% Ret.	Tagged	% Ret
1973	41	75.6	10					
1974	110	68.2	34	8.8	19	57.9	6	16.7
1975	70	34.2	76	1.3	19	63.2	4	
Total	221	58.8	120	3.3	38	60.5	10	10.0

DISCUSSION

Streams vary greatly in size, velocity, gradient, nature of the bed temperature and other features. Generally, streams change from the steep torrent to the sluggish meandering waterways as they proceed from source to mouth (Allen, 1969). Usually there are stages between the two extremes which are characterized by specific environmental features and a particular assemblage of fish species.

Many attempts have been made to associate particular fish faunas with these defined zones. Huet (1959) devised a scheme for European streams using four categories, naming each zone from the characteristic fish species found in them. In descending order of current velocities they are:

(1) The trout zone:
(2) The grayling zone:
(3) The barbel zone:
(4) The bream zone:

Each of these zones is characterized by a particular set of combinations of stream gradient and stream width. North American streams have been classified by zones by Lagler, et. al. (1962) as follows:

(1) Grayling
(2) Stream char
(3) Flowing water minnows and pike
(4) Basses
(5) Catfishes, suckers and quiet water minnows

As the gradient diminishes, the headwater fishes disappear and are replaced successively by others better adapted to the changing environment.

Fish populations in the Tongue River exhibit a succession from torrent zones fishes (trout) to the quiet zone fishes (catfish and suckers). Fish population data suggest that the Tongue River mimics the fish distribution, fish species diversity, and fish species zonation of the Yellowstone River, which is also extremely important to the scope of energy development. The results of the Tongue River Study will be compared to fish population studies currently being conducted in the Yellowstone main stem. This will aid in determining similarities with (or defining differences between) the Tongue sub-basin and the entire Yellowstone River Basin.

The objective of the Tongue River Reservoir segment of this study is to obtain baseline information on the fish populations of the reservoir and to document angler use and harvest rates. Decker Coal Company plans to expand their mining operations in the near future to include the east side of the reservoir. Questions raised concerning high sodium levels in the soils of the area makes it important to evaluate current fish population levels in the reservoir. Fish population data will be coordinated with information collected on a detailed limnology study of the reservoir. This information will allow us to evaluate the effects of a strip mine in close proximity to a reservoir. Other aspects of energy related developments will also be investigated and their impacts evaluated.

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IN-STREAM REQUIREMENTS OF THE BENTHIC MACROINVERTEBRATES OF THE TONGUE RIVER, MONTANA

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IN-STREAM REQUIREMENTS OF THE BENTHIC MACROINVERTEBRATES OF THE TONGUE RIVER, MONTANA

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IN-STREAM REQUIREMENTS
OF THE BENTHIC MACROINVERTEBRATES
OF THE TONGUE RIVER, MONTANA

James A. Gore

The benthic invertebrates, which represent virtually all trophic levels of the flow of energy through the aquatic ecosystem, and in particular the aquatic insects, represent the primary food source for the forage and game fishes. Any change in benthic invertebrate populations could result in changes in the overall composition of the river ecosystem.

The Tongue River in Montana is presently under study to determine the effect of possible streamflow alterations as a result of water needs by proposed energy-producing facilities in the area. It is assumed that the Tongue River represents a typical river system of the Fort Union coal field area. This paper is a report of the fall-winter composition of the benthic macroinvertebrates and is a partial inventory leading to a total seasonal index of the macroinvertebrate fauna of the Tongue River. In addition, preliminary data on niche requirements with regard to factors most affected by reduced stream discharge are presented.

Although the Tongue River has great oxbows typical of a meandering prairie river, the streamflow is not typically sluggish. Minimum daily flows during the fall and winter average 45 to 95 c.f.s. (cubic feet per second)(Montana State Department of Natural Resources and Conservation, Water Resources Division, 1974). With the exception of the lower few miles of the river, where the substrate is sand and deposited sediment, the Tongue River has a substrate of medium angular cobble (126 - 256 mm.) and ranges to large cobble in some areas. Riffle areas are quite common. The river is unique in the presence of both cold water and warm water habitats. The climate of the area is typical of the Northern Great Plains, generally considered to be semi-arid. Vegetation along the river consists of cottonwood, boxelder, willow, wild rose, and several species of the grasses.

METHODOLOGY

Hynes (1970) has stated that aquatic invertebrates, as a rule, have an inherent need for current, for the purposes of feeding and respiration. Riffle areas would provide the optimum feeding and dissolved oxygen situations. As riffle areas tend to be in the most shallow portions of the river, riffles will be affected by reduced discharge first. It can be assumed that maintenance of riffle areas will result in suitable conditions in the rest of the river system. A comprehensive study of the riffle forms will provide information on those forms most affected by reduced stream discharge.

For the purposes of this study eight areas were designated as collection points and collections were taken through the fall and winter months, 1974 - 1975. At each site two standard Hess samples were taken. The collections were then identified and counted to obtain an indication of relative abundance. For all practical purposes, hyporheic organisms were not examined with the exception of those shallow burrowers which might have been disturbed in the sampling procedure. In addition, standing water and pool forms are not considered as this study is primarily concerned with riffle forms.

Green (1971, 1974) has developed a multivariate statistical niche analysis which uses extracted discriminate functions to derive niche "maps" in the form of probability of occurence ellipses or survival ellipses. By superimposing various sets of environmental parameters on these "maps" one can predict the probability of occurence or survival of a given species or group of invertebrates. It has been determined that this method may be used to determine the in-stream flow requirements of the macroinvertebrates of the Tongue River. Rather than using nutrient concentrations, various discharge related parameters would be used in the multivariate analysis. A preliminary 25 sample transect was taken at Birney II in March, 1975, in order to determine feasability and acceptability of chosen variables which might determine the flow preferences of the macroinvertebrates which inhabit that area. Temperature, current velocity, measured with a Gurley microcurrent meter at six-tenths of the sample depth, sample depth, bed roughness, or profile, in which a substrate of one square meter covered with 33% medium cobble will measure 1.5, and the presence or absence of key invertebrates were determined to be those variables most likely to account for most of the distribution of the invertebrates. All variables were measured for each sample and were analyzed in the laboratory during the following months while spring run-off made additional field work on the river impossible.

COLLECTION POINT DESCRIPTIONS (see map)

Hosford I and II, Rosebud County, Montana are one mile apart and about five miles below the Tongue River Reservoir dam, ten miles south of the main entrance to the Hosford Ranch. This area is considered to be in the cold water habitat section with the river bordered by pasture grasslands.

Birney I and II, Rosebud County, Montana, are approximately two miles apart in the town of Birney, Montana. Birney I is located 100 meters below the entrance of Hanging Woman Creek. Birney II is located across from the Birney school below the entrance of a small sewage effluent. The river is bordered by cottonwoods, wild rose, and various grasses.

Ashland section, Rosebud County, Montana, is located beneath the bridge which crosses the Tongue River in the town of Ashland, Montana.

Viall section, Rosebud County, Montana, is located five miles above the Brandenberg bridge on the Viall Ranch.

S & H section, Custer County, Montana, is located one mile below the road leading to the river from the south entrance of the S & H Ranch, about 100 meters below a small waterfall in the section.

T & Y Diversion, Custer County, Montana, is located at the Montana Fish and Game Department fishing access site, 12 miles south of Miles City, Montana, and 30 meters below the spillway.

It should be noted that not all points were sampled in a given month due to inaccessibility to some areas during the winter months. However, each point was sampled once and most were sampled two or more times.

RESULTS

Collection area characteristics are listed in Table I.

The results of the collections are presented in tabular form (Table II) indicating total number of individuals and relative abundance, in percentage of total numbers, of the species collected. Those species indicated with an asterisk were present in the sample but in insufficient number to have a relative abundance value.

Where possible, organisms have been identified to the species level. The collection consists of nymphal and larval forms for the most part and it will be necessary to collect adult stages during emergence to fully identify those forms designated only by generic names.

Four of the five species of *Hydropsyche* have been designated as *Hydropsyche sp. a*, *H. sp. b*, *H. sp. c*, and *H. sp. d*.

Hydropsyche sp. a has a head pattern similar to *H. recurvata* of the *bifida* group designated by Ross (1944). However, variability in head patterns is so great that, as a single characteristic, identification can not be accurately made until adult forms are collected.

Hydropsyche sp. b is similar to the head pattern of *H. simulans*. However, the light border at the posterior margin of the head, as in *H. simulans*, does not exist in *H. sp. b*.

Hydropsyche sp. c is similar to *H. betteni* with the exception of lacking the light pattern at the posterior margin of the head.

Hydropsyche sp. d has no similarities to those larval forms presently described. The rust colored head has a pattern which encompasses the dashes near the eyes, as in *H. simulans*, and the crossed pattern of *H. recurvata*.

Two dryopoid beetles have been designated as *Stenelmis sp. a* and *Stenelmis sp. b*. *S. sp. a* generally resembles *S. douglasensis* and *S. sp. b* generally resembles *Ordobrevia nubifera* as designated by Brown (1972). However, the ranges of these two similar forms can not logically be extended to Montana. Brown states that several new species of *Stenelmis* are being reported from Idaho and Oregon. It is likely that *S. sp. a* and *S. sp. b* will be included in this group when fully described.

Where the designation "sp." occurs, it can be assumed that existing keys do not differentiate between larval forms at the specific level and that more than one species may be included.

Transect sample numbers and variable values are listed in Table III Since the transect samples were all taken at one place a temperature of 3.33°C is assigned to all samples. This variable is, thus, not significant for one transect, but, since several different transects at various points along the river will be taken and it has been shown that temperature does vary over the distance of the river, this variable will become significant as more transects are taken.

The presence of the various invertebrates in each sample is shown in Table IV.

ANALYSIS AND DISCUSSION

From the presented data, a kite-diagram (Figure I) is presented showing relative abundance and longitudinal distance. (Dashed lines indicate the presence of the organism in that section of the river, as determined by preliminary kick samples, but relative abundances have not been determined.)

It can be seen that the transition zone between cold water and warm water habitats (as delineated on the graph at Birney I) serves as the border for the upstream distribution of many organisms. Only a few insect genera (Baetis, Brachyptera, Hydropsyche, Simulium, and Metriocnemus) extend the entire length of the river through both cold and warm water environments. Neel (1963) states that if a reservoir is deep enough to become thermally stratified and has a hypolimnial drain, the discharge of cold water has a stabilizing effect on the thermal regime of the river below the dam, such that temperatures are considerably cooler in the summer and warmer in the winter. Hubbs (1972) has found that the reduction of 24-hour temperature fluctuations causes a marked decrease in the number of invertebrate species. Most organisms live best in a situation of thermal flux which synchronizes the life cycle and stimulates growth of insect instars (Ward, 1974). Additionally, Lemkuhl (1972) has found that diapause eggs, which require temperature fluctuations to hatch, will not hatch in areas influenced by hypolimnial release. Spence and Hynes (1971) have also found that lowered temperatures cause the increase in growth and abundance of periphyton which leads to a radical alteration of the substrate, eliminating many substrate specific organisms.

Pearson, Kramer, Franklin (1968) and Ward (1974) found that with increasing distance from the dam, atmospheric conditions and tributary waters combine to return the river to its pre-impoundment state and the numbers of invertebrate species increases.

The Tongue River Reservoir dam has a hypolimnial release and the biological situations described above are exhibited quite distinctly on the Tongue River.

Thus, it can be seen that in the area of the river affected by the hypolimnial release, the insect fauna is diminished and the dominant forms are the molluscs *Physa* and *Sphaerium*. From the collection point data (Table I), the cold water area is also an area of light turbidity and increased periphyton as exemplified by the dense mats of *Cladophora*. Where the original temperature regime is re-established (in the Birney area), the increase of the insect species is quite noticeable. Either because the higher summer temperatures are not conducive to mollusc growth or the insects are better able to utilize the available resources, *Physa* and *Sphaerium* are diminished or eliminated and the dominant forms are the hydropsychids and *Brachyptera*. The algal cover of *Cladophora* is reduced and *Nostoc* is present. Finally, as the river nears its junction with the Yellowstone River, a third community presents itself. Increased turbidity causes the amount of available light to be reduced and abrassive action of suspended particles fouls many insect gills ar causes alteration of the substrate to other than optimum conditions (Hynes, 1970). Thus, in the area of the lower river, where turbidity is high, the benthic

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fauna is dominated by *Cheumatopsyche* which can take advantage of the suspended matter in its feeding habits. The dominant algal form in this area, again being able to take advantage of less than optimum light conditions, is *Nostoc*.

Although a series of 25 samples is not sufficiently large to merit a complete multivariate analysis (between 200 and 300 will be taken for the final analysis), sufficient information is provided to substantiate continued efforts in this direction with the chosen variables.

Tables V, VI, and VII show the distribution of certain key invertebrates in relation to current, ranging from 0 to 115.0 cm/sec, depth from 6 to 32 cm., and bed roughness, from .034 to 2.951 (where 0 is a smooth surface and 3.0 is a large cobble substrate) respectively. The molluscs *Physa* and *Sphaerium* are included in this sample even though they do not normally occur in the Birney area or farther downstream. The transect samples were taken two weeks after the ice cover on the river had been removed and many molluscs had been uprooted and relocated in the Birney area. Since the water temperature was still fairly uniform over the length of the river at that time, the molluscs have persisted at Birney. As temperatures increase with approaching summer, the molluscs will be removed from the community by death and migration to cooler areas.

With the exception of one species, the invertebrates show a marked preference for a current velocity of over 16.0 cm/sec and most prefer even higher velocities of 27.0 cm/sec or more. In some groups, the specific limitations are shown remarkably well, even with this small number of samples. The members of the family Hydropsychidae show a marked preference for velocities between 38.0 cm/sec and 100.5 cm/sec (measured at six-tenths of the sample depth). A similar preference is shown in the mollusc Physa which seems to occur most frequently in the range of 38.0 cm/sec to 59.0 cm/sec, rarely being found outside this range. Similar ranges can be seen in the other Trichoptera presented. The elmid beetles show an interesting distribution in which the larval forms prefer a wider range of currents than the adults. In the Diptera, Simulium, a filter feeder like the hydropsychids, prefers a range of high velocities from 66.0 cm/sec to 115.0 cm/sec. It is the Simuliids which often provide the main source of food for the stoneflies which, in turn, are primary food sources for most forage fishes and some game fish.

Depth measurements do not seem to account for as much of the niche preference as current velocity. The Odonata show a preference for depths greater than 12 cm. The hydropsychids, again, show a narrow range of tolerances, from 14 to 32 cm., with fewer occuring outside this range. The elmid beetles show the distributions previously described with the larval forms showing a wider range of tolerances than the adult forms. The mollusc Physa again shows a defined range of 10 to 25 cm. depth preference.

Bed roughness seems to account for the least in niche requirements, with the exception of Simulium which prefers the smoother surfaces and Atherix which prefers the rougher surfaces. The small sample size, to this date, may account for the limited amount of information derived from the bed roughness data. In addition, a discriminant function, which has not been extracted due to small sample size, which combines bed roughness with depth or current velocity may provide more information and serve to further narrow the optimum instream niche requirements of the macroinvertebrates. When the full set of 200 to 300 samples are taken (in the monthes of July through September, 1975) niche requirements and tolerance limits which will include the combination of all variables will be presented.

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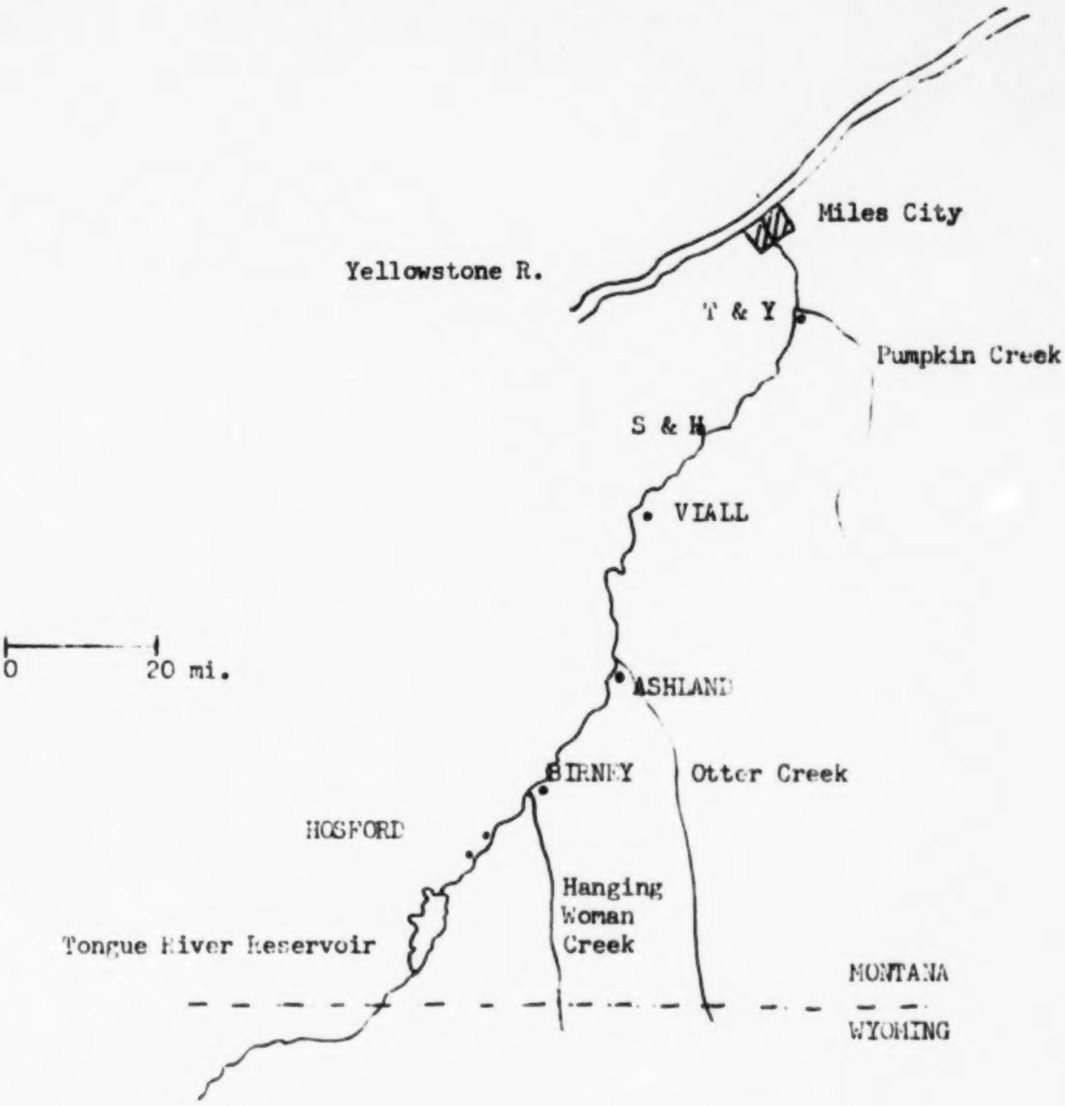
Miles City
Yellowstone R.
T & Y
Pumpkin Creek
S & H
VIALL
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ASHLAND
BIRNEY
Otter Creek
HOSFORD
Hanging
Woman
Creek
Tongue River Reservoir
MONTANA
WYOMING

Figure I. Location of Sample Sites, Tongue River

TABLE I

Collection Area Characteristics

AREA	TURBIDITY	SAMPLE DEPTH	SUBSTRATE	PERIPHYTON
HOSFORD I HOSFORD II	Light	30 - 45 cm.	Medium to large cobble	*Cladophora*, *Spirogyra*, dense mats
BIRNEY I BIRNEY II	Light to moderate	30 - 45 cm.	Medium to large cobble	*Cladophora*, *Spirogyra*, sparse mat
ASHLAND	Light	30 cm.	Medium to small cobble	*Nostoc*, sparse Cladophora
VIALL	Moderate	30 - 45 cm.	Medium cobble	*Nostoc*, sparse Cladophora
S & H	Moderate to Heavy	30 - 45 cm.	Bedrock with medium cobble	Heavy Nostoc
T & Y	Heavy	30 - 45 cm.	Medium cobble and sand	Heavy *Nostoc*

TABLE II

Relative Abundances

	HOSFORD I	HOSFORD II	BIRNEY I	BIRNEY II	ASHLAND	VIALL	S & H	T & Y
	(98)	(119)	(247)	(773)	(76)	(83)	(51)	(135)
EPHEMEROPTERA								
Choroterpes sp.			1.6	.39		2.4		1.5
Paraleptophlebia debilis			.81	.78	1.3			
Leptophlebia sp.			.4					
Baetis sp.		2.5	.4	3.2			2.0	3.7
Stenonema reesi			2.4	1.0	2.6	1.2	2.0	6.0
Rhithrogena sp.				.1	3.9		2.0	
Ephemerella sp.			2.4	2.1	3.9	3.6	5.9	3.0
Tricorythodes sp.							4.0	
Tricorythodes minutus		.8	3.6	3.0	2.6			
ODONATES								
Ophiogomphus morrisoni			1.6	.8		2.4	2.0	
Argia sp.		.8						
Hetaerina americanus			*	*				
PLECOPTERA								
Brachyptera sp.	1.0	1.7	13.0	21.6	18.4		3.9	1.5
Leuctra sp.		.8	4.5	5.6	6.6			

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TABLE II (cont.)

	HOSFORD I	HOSFORD II	BIRNEY I	BIRNEY II	ASHLAND	VIALL	S & H	T & Y
Capnia limata				*	5.3			
Isogenus modestus					1.3	1.2		
Isogenus frontalis						1.2		
Acroneuria abnormis			2.4	2.5	1.3	2.4		
LEPIDOPTERA								
Cataclysta sp.			.4	.7				
TRICHOPTERA								
Cheumatopsyche sp.			15.0	9.3	6.6	26.5	25.5	64.4
Hydropsyche bifida			13.4	9.2	11.8	14.5	11.8	3.0
H. sp. a	19.4	4.2	6.1	14.4	6.6	13.3		
H. sp. b	2.0	.8		.1	1.3	3.6	3.9	
H. sp. c	23.5	8.4	8.1	8.4	1.3	18.1		
H. sp. d			2.0	.4				
Brachycentrus numerosus				.3				3.7
Brachycentrus americanus					1.3	2.4	11.8	3.7
Athripsodes sp.			2.4	2.2	2.6			1.5

TABLE II (cont.)

	HOSFORD I	HOSFORD II	BIRNEY I	BIRNEY II	ASHLAND	VIALL	S & H	T & Y
Leptocella sp.	2.0		4.1	.3				
Limnophilidae	1.0			*				3.0
COLEOPTERA								
Laccobius sp.								.7
Stenelmis sp. a			5.7	3.1	1.3	7.2	7.8	3.0
Stenelmis sp b	12.2	20.2	5.3	7.5	2.6			
Dubiraphia sp.			*	*				
DIPTERA								
Simulium sp.		12.6	.4	.1			15.7	1.5
Metriocnemus sp.			4.1	2.5	4.0			
Chironomidae (other spp.)			*	*				
Atherix sp.				.4	10.5			
TURBELLARIA								
Dugesia sp.			*	*	*	*	*	*
MOLLUSCA								
Ferrissia rivularis		.8			1.3			
Physa sp.	15.3	31.9						
Lymnea sp.	*	*						
Gyraulus sp.	*	*						

TABLE II (cont.)

	HOSFORD I	HOSFORD II	BIRNEY I	BIRNEY II	ASHLAND	VIALL	S & H	T & Y
Elliptio sp.							2.0	
Pisidium sp.	*	*						
Sphaerium simile	23.5	14.3						
CRUSTACEA								
Daphnia sp.			*	*				
Hyallela azteca			*	*	*	*		
Gammarus sp.			*	*				

FIGURE II

Kite-diagram showing relative invertebrate abundance vs. longitudinal distance

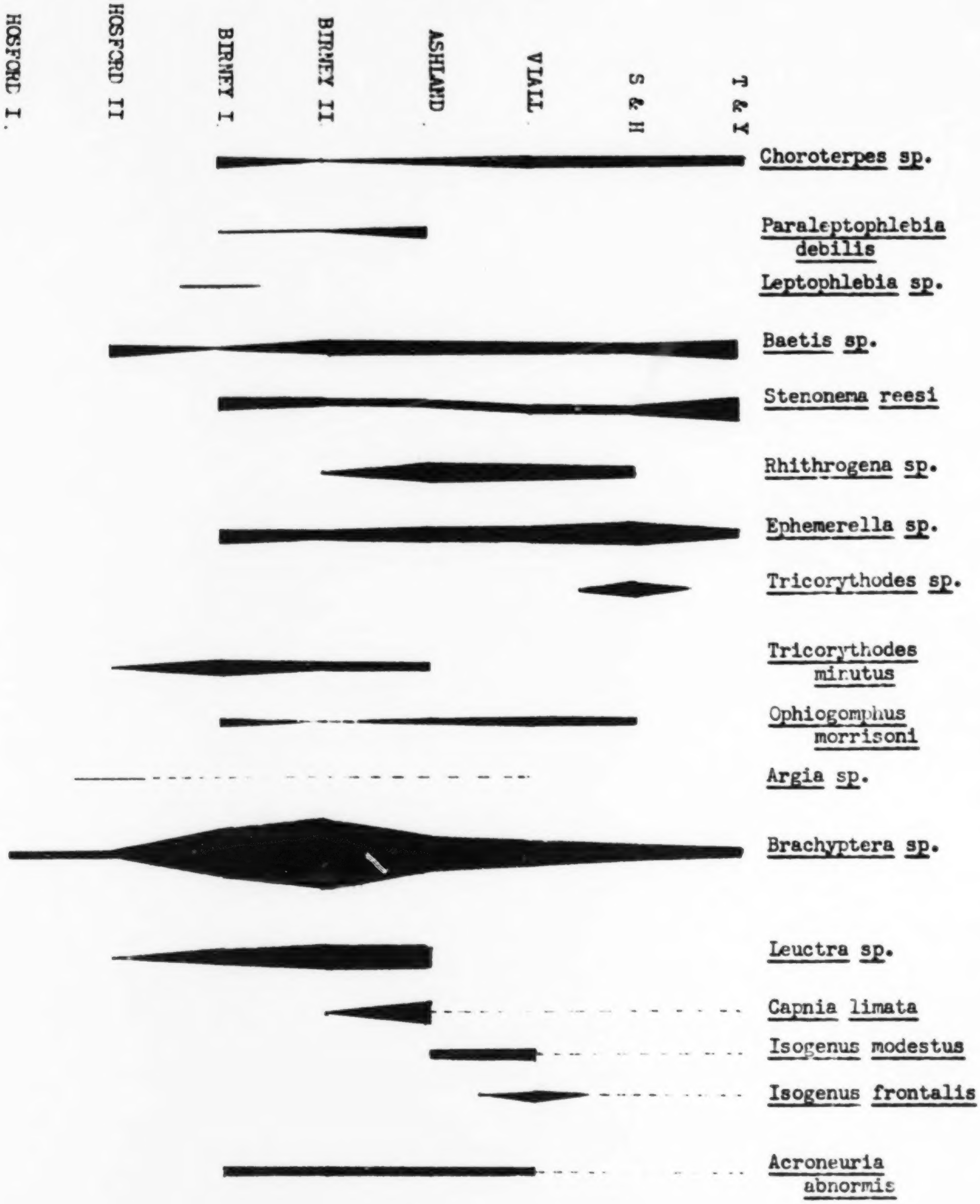

FIGURE II (cont.)

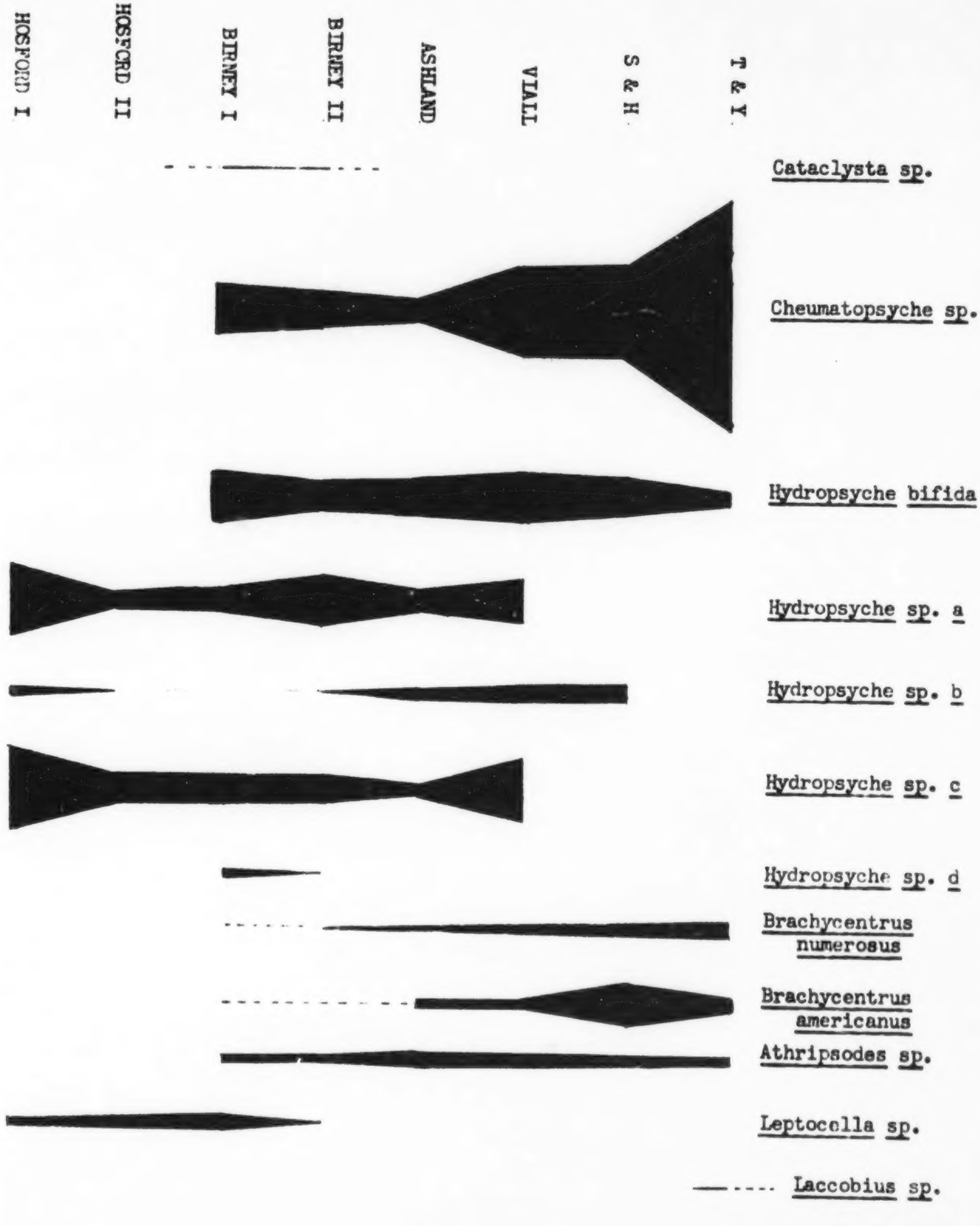

FIGURE II (cont.)

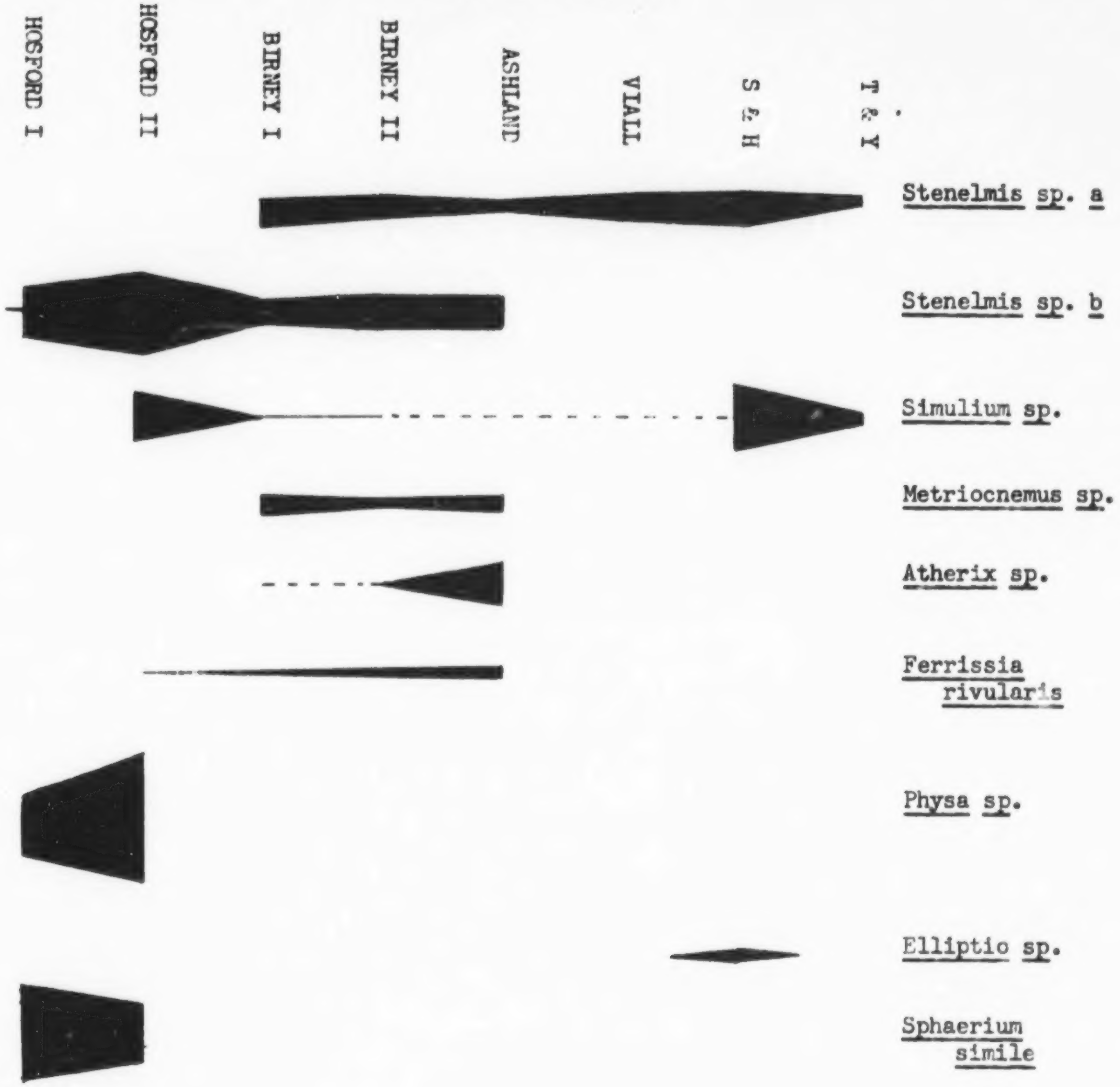

TABLE III

Sample numbers and corresponding variable values

Sample #	Depth (cm.)	Current (cm/sec)	Bottom Roughness Index
1	12.5	26.999	2.72744
2	14.0	37.999	2.95144
3	19.0	42.499	2.33903
4	24.0	61.999	1.38884
5	25.0	58.999	1.83672
6	21.0	51.499	1.43647
7	20.0	60.0	1.8397
8	27.0	65.499	1.85699
9	25.0	100.5	2.14239
10	30.0	88.999	1.7723
11	12.0	0	1.5563
12	12.0	51.499	1.37714
13	17.0	49.5	1.34742
14	10.0	115.999	.63413
15	17.0	57.999	.99209
16	17.0	75.0	1.54799
17	15.0	93.999	2.68347
18	25.0	69.0	1.98627
19	32.0	63.0	1.50071
20	31.0	84.0	2.48797
21	11.0	79.999	2.00492
22	15.0	54.0	2.48061
23	19.0	70.999	2.68323
24	6.0	31.999	1.82882
25	8.0	15.999	2.24626

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TABLE IV

Occurance of invertebrates in each sample

Sample #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Choroterpes sp.																									
Paraleptophlebia debilis																									
Leptophlebia sp.																									
Baetis sp.	+	+	+		+	+	+	+	+	+		+	+	+		+	+	+	+		+	+	+	+	
Stenonema reesi	+	+	+	+		+	+		+	+		+	+						+	+			+		
Rhithrogena sp.																									
Ephemerella sp.	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+				+
Tricorythodes sp.																									
Tricorythodes minutus	+	+			+																				
Ophiogomphus morrisoni		+	+		+				+	+		+	+				+	+	+	+			+		
Argia sp.		+			+																				
Hetaerina americanus												+													
Brachyptera sp.	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+
Leuctra sp.	+		+		+	+		+	+	+		+		+	+		+	+	+	+	+	+	+	+	+
Capnia limata	+			+			+	+		+	+	+									+		+	+	
Isogenus modestus																									
Isogenus frontalis																									
Acroneuria abnormis	+	+	+	+	+	+		+	+			+	+	+	+		+	+	+	+	+	+	+		
Cataclysta sp.															+										
Cheumatopsyche sp.		+		+	+	+	+		+	+					+	+	+	+	+	+		+			
Hydropsyche bifida		+		+		+	+		+	+			+				+	+	+	+					
Hydropsyche sp. a		+	+	+	+	+	+		+	+		+	+		+	+	+	+	+	+			+		

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Table IV (cont.)

Sample #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Hydropsyche sp. b				+	+				+											+	+		+		
Hydropsyche sp. c		+	+	+	+	+	+	+	+	+		+	+		+	+	+	+	+	+	+	+	+	+	
Hydropsyche sp. d				+	+		+		+	+							+	+		+					
Brachycentrus numerosus																									
Brachycentrus americanus		+													+	+		+							
Athripsodes sp.			+	+				+					+	+	+		+	+		+	+				
Leptocella sp.			+		+	+						+	+		+			+		+	+				
Limnophilidae		+		+	+		+											+							
Laccobius sp.																									
Stenelmis sp. a (A)		+			+	+							+					+		+					
Stenelmis sp. a (L)	+	+	+		+		+		+	+		+	+		+		+	+	+	+	+			+	
Stenelmis sp. b (A)					+				+										+						
Stenelmis sp. b (L)		+			+	+							+	+	+	+		+		+	+			+	
Dubiraphia sp.												+			+			+					+		
Simulium sp.								+						+				+							
Metriocnemus sp.	+			+	+	+	+		+	+		+	+		+	+	+	+	+	+	+		+		
Chironomidae (other)	+		+		+		+		+				+	+	+	+	+				+	+			
Atherix sp.		+			+													+						+	
Ferrissia rivularis																									
Physa sp.		+	+		+	+						+		+	+										
Lymnea sp.																				+					
Gyraulus sp.		+																							
Elliptio sp.																									
Pisidium sp.	+												+					+			+				
Sphaerium simile					+	+	+		+			+	+	+	+		+	+	+	+	+	+	+		

TABLE V

Distribution of invertebrates as a function of current velocity

Current (cm/sec)	Sample #	Baetis sp.	Stenonema reesi	Ephemerella sp.	Tricorythodes minutus	Ophiogomphus morrisoni	Argia sp.	Hetaerina americanus	Stenelmis sp. a (A)	Stenelmis sp. a (L)	Stenelmis sp. b (A)	Stenelmis sp. b (L)	Dubiraphia sp.
0	11												
16.0	25			+									
27.0	1	+	+	+	+					+			
32.0	24	+								+		+	
38.0	2	+	+	+	+	+	+		+	+		+	
42.5	3	+	+	+		+				+			
49.5	13	+	+	+		+			+	+		+	
51.5	6	+	+	+					+			+	
51.5	12	+	+	+		+		+		+			+
54.0	22	+											
58.0	15			+						+		+	+
59.0	5	+		+	+	+	+		+	+	+	+	
60.0	7	+	+	+						+			
62.0	4		+	+									
63.0	19	+	+	+		+				+	+		
65.5	8	+		+									
69.0	18	+		+		+			+	+		+	+
71.0	23	+	+			+							+
75.0	16	+		+								+	
80.0	21	+		+						+		+	
84.0	20		+	+		+			+	+		+	
89.0	10	+	+	+		+				+			
94.0	17	+		+		+				+			
100.5	9	+	+	+		+				+	+		
115.0	14	+		+								+	

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TABLE V (cont.)

Current (cm/sec)	Sample #	*Simulium* sp.	*Metriocnemus* sp.	*Atherix* sp.	*Brachyptera* sp.	*Leuctra* sp.	*Capnia limata*	*Acroneuria abnormis*	*Physa* sp.	*Sphaerium simile*
0	11						+			
16.0	25				+	+				
27.0	1		+		+	+	+	+		
32.0	24			+	+	+	+			
38.0	2			+	+			+	+	
43.0	3		+		+	+		+	+	
49.5	13				+	+		+		+
51.5	6				+	+		+	+	+
51.5	12		+		+	+	+	+	+	+
54.0	22				+	+		+		+
58.0	15		+		+	+		+	+	+
59.0	5		+	+	+	+		+	+	+
60.0	7		+		+		+			+
62.0	4		+		+		+	+		
63.0	19		+		+	+		+		+
65.5	8	+			+	+	+	+		
69.0	18	+	+	+	+	+		+		+
71.0	23		+		+	+	+	+		+
75.0	16		+		+					
80.0	21		+		+	+	+	+		+
84.0	20		+		+	+		+		+
89.0	10		+		+	+	+			
94.0	17		+		+	+		+		+
100.5	9		+		+	+		+		+
115.0	14	+			+	+		+	+	+

TABLE V (cont.)

Current (cm/sec)	Sample #	*Cheumatopsyche sp.*	*Hydropsyche bifida*	*Hydropsyche sp. a*	*Hydropsyche sp. b*	*Hydropsyche sp. c*	*Hydropsyche sp. d*	*Brachycentrus americanus*	*Athripsodes sp.*	*Leptocella sp.*
0	11									
16.0	25									
27.0	1									
32.0	24					+				
38.0	2	+	+	+		+		+		
43.0	3			+		+			+	+
49.5	13		+	+		+			+	+
51.5	6	+	+	+		+				+
51.5	12			+		+				
54.0	22	+				+				
58.0	15	+		+		+		+	+	+
59.0	5	+		+	+	+				+
60.0	7	+	+	+		+	+			
62.0	4	+	+	+	+	+	+		+	
63.0	19	+	+	+		+				
65.5	8					+			+	
69.0	18	+	+	+		+	+	+	+	+
71.0	23			+	+	+				
75.0	16	+		+		+		+		
80.0	21				+	+			+	+
84.0	20	+	+	+	+	+	+		+	+
89.0	10	+	+	+		+	+			
94.0	17	+	+	+		+	+		+	
100.5	9	+	+	+	+	+	+			
115.0	14								+	

TABLE VI

Distribution of invertebrates as a function of stream depth

Depth (cm.)	Sample #	*Baetis* sp.	*Stenonema reesi*	*Ephemerella* sp.	*Tricorythodes minutus*	*Ophiogomphus morrisoni*	*Argia* sp.	*Hetaerina americanus*	*Brachyptera* sp.	*Leuctra* sp.	*Capnia limata*	*Acroneuria abnormis*
6	24	+							+	+	+	
8	25			+					+	+		
10	14	+		+					+	+		+
11	21	+		+					+	+		+
12	11										+	
12	12	+	+	+		+		+	+	+	+	+
12.5	1	+	+	+	+				+	+	+	+
14	2	+	+	+	+	+	+		+			+
15	17	+		+		+			+	+		+
15	22	+							+	+		+
17	13	+	+	+		+			+			+
17	15			+					+	+		+
17	16	+		+					+			
19	23	+	+			+			+	+	+	+
19	3	+	+	+		+			+	+		+
20	7	+	+	+					+		+	
21	6	+	+	+					+	+	+	+
24	4		+	+					+		+	+
25	9	+	+	+		+			+	+		+
25	5	+		+	+	+	+		+	+		+
25	18	+		+		+			+	+		+
27	8	+		+					+	+	+	+
30	10	+	+	+		+			+	+	+	
31	20		+	+		+			+	+		+
32	19	+	+	+		+			+	+		+

TABLE VI (cont.)

Depth (cm.)	Sample #	*Stenelmis* sp. *a* (A)	*Stenelmis* sp. *a* (L)	*Stenelmis* sp. *b* (A)	*Stenelmis* sp. *b* (L)	*Dubiraphia* sp.	*Metriocnemus* sp.	*Atherix* sp.	*Simulium* sp.	*Physa* sp.	*Sphaerium simile*
6	24		+		+			+			
8	25										
10	14				+					+	+
11	21		+		+		+				+
12	11										
12	12		+			+	+			+	
12.5	1		+				+				
14	2	+	+		+			+	+	+	
15	17		+				+				+
15	22										+
17	13	+	+		+		+				+
17	15		+		+	+	+			+	+
17	16				+		+				
19	23					+	+				+
19	3		+							+	
20	7		+				+				+
21	6	+			+					+	+
24	4						+				
25	9		+	+			+				+
25	5	+	+	+	+		+	+		+	+
25	18	+	+		+	+	+	+	+		+
27	8								+		
30	10		+				+				
31	20	+	+		+		+				+
32	19		+	+			+				+

TABLE VI (cont.)

Depth (cm.)	Sample #	*Cheumatopsyche* sp.	*Hydropsyche bifida*	*Hydropsyche* sp. a	*Hydropsyche* sp. b	*Hydropsyche* sp. c	*Hydropsyche* sp. d	*Brachycentrus americanus*	*Athripsodes* sp.	*Leptocella* sp.
6	24					+				
8	25									
10	14								+	
11	21				+	+			+	+
12	11									
12	12			+		+				+
12.5	1									
14	2	+	+	+		+		+		
15	17	+	+	+		+	+			
15	22	+				+				
17	13		+	+		+			+	+
17	15	+		+		+		+	+	+
17	16	+		+		+		+	+	
19	23			+	+	+				
19	3			+		+			+	+
20	7	+	+	+		+	+			
21	6	+	+	+		+				+
24	4	+	+	+	+	+	+		+	
25	9	+	+	+	+	+	+			
25	5	+		+	+	+				+
25	18	+	+	+		+	+	+	+	+
27	8					+			+	
30	10	+	+	+		+	+			
31	20	+	+	+	+	+	+		+	+
32	19	+	+	+		+				

TABLE VII

Distribution of invertebrates as a function of bed roughness

Roughness Index	Sample #	Baetis sp.	Stenonema reesi	Ephemerella sp.	Tricorythodes minutus	Ophiogomphus morrisoni	Argia sp.	Hetaerina americanus	Brachyptera sp.	Leuctra sp.	Capnia limata	Acroneuria abnormis
.634	14	+		+					+	+		+
.992	15			+					+	+		+
1.347	13	+	+	+		+			+			+
1.377	12	+	+	+		+		+	+	+	+	+
1.388	4		+	+					+		+	+
1.436	6	+	+	+					+	+		+
1.5	19	+	+	+		+			+	+		+
1.547	16	+		+					+			
1.556	11										+	
1.772	10	+	+	+		+			+	+	+	
1.828	24	+							+	+	+	
1.836	5	+		+	+	+	+		+	+		+
1.839	7	+	+	+					+		+	
1.856	8	+		+					+	+	+	+
1.986	18	+		+		+			+	+		+
2.004	21	+		+					+	+	+	+
2.142	9	+	+	+		+			+	+		+
2.246	25			+					+	+		
2.339	3	+	+	+		+			+	+		+
2.48	22	+							+	+		+
2.457	20		+	+		+			+	+		+
2.6632	23	+	+			+			+	+	+	+
2.6634	17	+		+		+			+	+		+
2.727	1	+	+	+	+				+	+	+	+
2.951	2	+	+	+	+	+	+		+			+

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TABLE VII (cont.)

Roughness Index	Sample #	Cheumatopsyche sp.	Hydropsyche bifida	Hydropsyche sp. a	Hydropsyche sp. b	Hydropsyche sp. c	Hydropsyche sp. d	Brachycentrus americanus	Athripsodes sp.	Leptocella sp.
.634	14					+			+	
.992	15	+		+		+		+	+	+
1.347	13		+	+		+			+	+
1.377	12			+		+				+
1.388	4	+	+	+	+	+	+		+	
1.436	6	+	+	+		+				+
1.5	19	+	+	+		+				
1.547	16	+		+		+		+		
1.556	11									
1.772	10	+	+	+		+	+			
1.828	24					+				
1.836	5	+		+	+	+				+
1.839	7	+	+	+		+	+			
1.856	8					+			+	
1.986	18	+	+	+		+	+	+	+	+
2.004	21				+	+			+	+
2.142	9	+	+	+	+	+	+			
2.246	25									
2.339	3		+			+			+	+
2.48	22	+				+				
2.487	20	+	+	+	+	+	+		+	+
2.6832	23			+	+	+				
2.6834	17	+	+	+		+	+		+	
2.727	1									
2.951	2	+	+	+		+		+		

TABLE VII (cont.)

Roughness Index	Sample #	*Stenelmis* sp. a (A)	*Stenelmis* sp. a (L)	*Stenelmis* sp. b (A)	*Stenelmis* sp. b (L)	*Dubiraphia* sp.	*Simulium* sp.	*Metriocnemus* sp.	*Atherix* sp.	*Physa* sp.	*Sphaerium simile*
.634	14				+		+			+	+
.992	15		+		+	+		+		+	+
1.347	13	+	+		+			+			+
1.377	12		+		+			+		+	+
1.388	4							+			
1.436	6	+			+					+	+
1.5	19		+	+				+			+
1.547	16				+			+			
1.556	11										
1.772	10		+					+			
1.828	24		+		+				+		
1.836	5	+	+	+	+			+	+	+	+
1.839	7		+					+			
1.856	8						+				
1.986	18	+	+		+	+	+	+			+
2.004	21		+		+			+			+
2.142	9		+	+				+			+
2.246	25										
2.339	3		+							+	
2.48	22										+
2.487	20	+	+	+				+			+
2.6832	23					+		+			+
2.6834	17		+					+			+
2.727	1		+					+			
2.951	2	+	+	+					+	+	